EFFECT OF NITROGEN, SILICON AND ORGANIC FERTILIZER MANAGEMENT ON GROWTH, YIELD AND LODGING OF TRADITIONAL AROMATIC RICE

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CERTIFICATE

This is to certify that the thesis entitled **"EFFECT OF NITROGEN, SILICON AND ORGANIC FERTILIZER MANAGEMENT ON GROWTH, YIELD AND LODGING OF TRADITIONAL AROMATIC RICE "** submitted to the Department of Agricultural Botany, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTERS OF SCIENCE (M.S.)** in **AGRICULTURAL BOTANY**, embodies the result of a piece of bonafide research work carried out by **PROTIVA SINHA**, Registration No. **18-09137** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

I further certify that any help or source of information, received during the course of this investigation has been duly acknowledged.

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Dedicated to

My

Beloved Parents

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The Author

EFFECT OF NITROGEN, SILICON AND ORGANIC FERTILIZER MANAGEMENT ON GROWTH, YIELD AND LODGING OF TRADITIONAL AROMATIC RICE

ABSTRACT

A field experiment was carried out at Experimental Field of Department of Agricultural Botany, Sher-e-Bangla Agricultural University (SAU), Dhaka to study the effect of nitrogen, silicon and organic fertilizer management on growth, yield and lodging of traditional aromatic rice. The cultivars were grown during Boro season, 2019-20 (November, 2019 to May, 2020). The experiment consisted of two factors; Factor-A: three aromatic rice varieties *viz*. V_1 = Badshabhog, V_2 = Chiniatab (awnless) and V_3 = Kataribhog (awnless) and Factor B: four levels of fertilizer management *viz*. T_1 = {30(BS) +20 (MT) + 10 (BPI)} kg ha^{-1} + no silicon and cow-dung, T_2 = {30(BS) +20 (MT) + 10 (BPI)} kg ha^{-1} + silicon (450 SiO_2 kg ha^{-1}) + no cow-dung, T_3 = {30(BS) +20 (MT) + 10 (BPI)} kg ha^{-1} + No silicon + cow-dung (6 t ha^{-1}) and T_4 = {30(BS) +20 (MT) + 10 (BPI)} kg ha^{-1} + silicon (450 SiO_2 kg ha^{-1}) + cow-dung (6 t ha^{-1}) (BS= basal dose; MT= mid-tillering and BPI= before panicle initiation). The experiment was set up in two factors Randomized Complete Block Design (RCBD) with three replications. In case of varietal performance, V_1 (Badshabhog) showed highest plant height, number of tillers $hill^{-1}$, leaf area index, 4^{th} internode diameter, culm height and culm dry weight, length and fresh weight of internodes and chlorophyll content compared to V_2 (Chiniatab) and V_3 (Kataribhog). The highest number of filled grains $panicle^{-1}$, grain weight $hill^{-1}$, ratio of spikelet number to LA and ratio of yield sink to LA were also achieved by V_1 (Badshabhog) and this variety showed highest grain yield (2.52 t ha^{-1}) which is 3.28% and 11% higher than V_2 (Chiniatab) and V_3 (Kataribhog), respectively. Similarly, variety V_2 (Chiniatab) showed highest lodging resistance and aroma quality which was very close to the variety V_1 (Badshabhog) whereas V_3 (Kataribhog) showed least performance. Again, in terms of fertilizer management practices, plant height, tiller number, leaf area, 4^{th} internode diameter, culm height and dry weight, length and fresh weight of internodes and chlorophyll content increased progressively with increasing fertilizers application and best result was achieved from T_4 treatment compared to control treatment T_1. The highest number of filled grains $panicle^{-1}$, grain weight $hill^{-1}$, ratio of spikelet number to LA and ratio of yield sink to LA were also found from T_4 treatment. This treatment (T_4) also showed highest grain yield (2.76 t ha^{-1}) with is 40.82% higher than control and 5.34% and 20% higher than T_2 and T_3, respectively. The best performance of lodging resistance was performed by T_4 followed by T_2 but there was no significant effect of fertilizer management on aroma quality. In case of treatment combinations, V_1T_4 performed best in producing higher yield of rice (2.89 t ha^{-1}) due to production of higher spikelets $panicle^{-1}$, number of filled grains $panicle^{-1}$ and grain weight $hill^{-1}$ from V_1T_4 whereas V_3T_1 showed the lowest yield (1.86 t ha^{-1}). Similarly, the treatment combination of V_1T_4, V_2T_2 and V_2T_4 showed strong lodging resistance and V_2T_1, V_2T_2, V_2T_3 and V_2T_4 showed strong aroma quality of rice. These results suggested that fertilizer management plays a vital role for improving stem strength in different rice cultivars. Regarding yield and lodging resistance, firstly Badshabhog and next to Chiniatab and Kataribhog with SiO_2 and cow-dung can be recommended. To obtain best aroma, Chiniatab can be recommended with the same treatment.

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ABBREVIATIONS AND ACRONYMS

AEZ	=	Agro-Ecological Zone
BBS	=	Bangladesh Bureau of Statistics
BCSRI	=	Bangladesh Council of Scientific Research Institute
cm	=	Centimeter
CV %	=	Percent Coefficient of Variation
DAS	=	Days After Sowing
DMRT	=	Duncan's Multiple Range Test
et al.,	=	And others
e.g.	=	exempli gratia (L), for example
etc.	=	Etcetera
FAO	=	Food and Agricultural Organization
g	=	Gram (s)
i.e.	=	id est (L), that is
Kg	=	Kilogram (s)
LSD	=	Least Significant Difference
m^2	=	Meter squares
ml	=	MiliLitre
M.S.	=	Master of Science
No.	=	Number
SAU	=	Sher-e-Bangla Agricultural University
var.	=	Variety
^oC	=	Degree Celceous
%	=	Percentage
NaOH	=	Sodium hydroxide
GM	=	Geometric mean
mg	=	Miligram
P	=	Phosphorus
K	=	Potassium
Ca	=	Calcium
L	=	Litre
µg	=	Microgram
USA	=	United States of America
WHO	=	World Health Organization

CHAPTER I

INTRODUCTION

Rice is the foremost staple food for more than 50% of the world's population, growing in at least 114 countries under diverse condition (Anis *et al.,* 2016; Khatun *et al.,* 2018). There is an upward shift in demand for quality rice worldwide as people change their eating habits due to improvement of economic condition and consciousness (Rashid *et al*., 2016; Nath *et al.,* 2018).

Aromatic or fine rice have export potential, taste as well as eating qualities. It commands a much higher price than ordinary brand rice (Mannan *et al*., 2012; Roy *et al*., 2018). In fact aromatic rice is very popular in the national and the international markets (Yoshihito, 2005). Cultivation of aromatic rice has been gaining popularity in Bangladesh over the recent years, because of its huge demand both for internal consumption and export (Dutta *et al.* 2002). However, the choice of grain quality depends on the consumers' income. The demand for aromatic rice has been increased rapidly due to economic upliftment of the people of Bangladesh (BRRI, 2016). Most of the well-off people preferred long, scented fine rice (Biswas *et al.,* 1992). Despite the generally favourable agro-climatic conditions, area of aromatic rice cultivation is less than 2% of the national rice acreage of Bangladesh (Ashrafuzzaman *et al.,* 2009). So, higher priority is to be given on growing aromatic rice to meet up the increasing demand of it and earning foreign currency.

There are a large number of indigenous/traditional fine-grained popular aromatic rice cultivars in Bangladesh. Traditional aromatic rice cultivars are comparatively taller than modern one and they are susceptible to lodging. It is one of the major constraints to get desirable yield from traditional aromatic rice cultivars. Lodging can reduce up to 80% grain yield and causes severe knock-on effects including grain quality (IRRI*,* 2008). Moreover, most of the traditional aromatic rice genotypes are photoperiod-sensitive and suitable for growing in

Aman season (Alam, 1998; Islam *et al.,* 2013). The production cost of traditional aromatic rice is low compared to that of coarse rice (Islam *et al.,* 2015). The average grain yield of rice in *Aman* season is lower than that of *Boro* season due to prevailing climatic conditions. *Boro* season is more favourable for cultivating rice and getting higher grain yield compare to *Aman* and *Aus* seasons (Haque, 2014; Ashrafuzzaman *et al.,* 2009; BRRI, 2013). For this and getting higher yield of rice, farmers are willing to grow aromatic fine rice in *Boro* season (Mannan *et al*., 2012; BRRI, 2017). But the crop faces heading or flowering problem due to gradual increasing of day length in *Boro* season. As yet, BRRI has developed only one aromatic rice variety, BRRI dhan 50 (Banglamoti) for *Boro* season. Its grain yield is comparatively higher than traditional one. But its quality is not up to the mark compared to the traditional same.

So, appropriate method and suitable cultivars/varieties will be found out or developed for expanding cultivation of aromatic rice in *Boro* season. The main risk to cultivate the photo-period sensitive traditional aromatic rice cultivars in *Boro* season is that they will not flower when seeded beyond the cutoff date in November (BRRI, 2003; Mannan *et al*., 2012). In our recent experiment, traditional photo-sensitive rice genotypes showed much variation in receiving photo-induction at seedling stage. Some of them produced normal panicle (flowers) and gave a good harvest when they seeded in first to second week of November. Silicon fertilization reduced lodging in rice (Lee *et al.,* 1990; Swain and Rout *et al*., 2020). Top and/or late top dressing of nitrogen increased susceptibility to lodging. In many cases, yield decreases when nitrogen rates are more than optimal. But due to synergistic effect the application of silicon has the potential to raise the optimum nitrogen rates, thus enhancing productivity of rice. Moreover, silicon application helps to increase lodging resistance in rice (Akter *et al.,* 2018; Zhang *et al.,* 2010). Organic fertilizer improves aroma, grain quality and yield of aromatic rice. However, research work on lodging resistance of traditional aromatic rice cultivars in *Boro* season is absent in our country even in our surroundings. Considering these propositions, the present research project was undertaken with a view to improving lodging resistance, flowering behaviour and grain quality of traditional aromatic rice cultivars in *Boro* season

OBJECTIVE(S)

This research work were designed to achieve the following objectives -

1. To assess the effect of nitrogen, silicon and organic fertilizer management on lodging resistance, growth behaviour, aroma quality and yield of traditional aromatic rice cultivars in *Boro* season
2. To develop a way for improving lodging resistance and grain quality of traditional aromatic rice cultivars.

CHAPTER II

REVIEW OF LITERATURE

Rice is considered as main food crop of Bangladesh. Limited research works have been done in different parts of the world as well as in Bangladesh to study the effect of nitrogen, silicon and organic fertilizer management on growth, yield and lodging of traditional aromatic rice. However, some of the literatures relevant to effect of variety and fertilizer management are reviewed in this chapter.

2.1 Effect of variety on growth and yield of rice

Khatun *et al*. (2020) conducted a field experiment with six rice varieties to determine their growth and yield performance. The results revealed that in all rice varieties maximum growth performance observed at 58-68 Days after transplanting and maximum dry matter production was observed at 68 days after transplanting. Maximum number of filled spikelet observed in Binadhan-17 (164.89/panicle) and that was significantly different from other varieties. Percent of sterile spikelet was highest in BRRI dhan39 (12.9%) and that was statistically similar with Binadhan-16 (11.96%) and BRRI dhan33 (12.36%). Maximum 1000-seed weight was observed in Binadhan-17 (27.25 g). Highest grain yield was obtained from Binadhan-17 (6.13 t/h) that was significantly different from other varieties. Lowest grain yield observed in BRRI dhan39 (4.49 t/h) that was statistically similar to BRRI dhan33 (4.57 t/h) and Binadhan-7 (4.86 t/h).

Rashid *et al*. (2017) conducted an experiment to evaluate the yield performance of seven aromatic rice varieties of Bangladesh *viz*. Jirakatari, Chiniatab, Chinigura, Kataribhog, Kalizara, Badshabhog and BRRI dhan34. The entire yield contributing attributes and quality parameters varied significantly among the aromatic rice varieties. The highest plant height (167.0 cm) was found in the variety Chinigura and the lowest (120.1 cm) in the variety Chiniatab. In the variety Kataribhog number of filled grains panicle^{-1} was found highest (255.6) and the lowest (130.7) was recorded in the variety Badshabhog. Badshabhog produced the highest 1000-grain weight (18.3 g) and the lowest (11.4 g) was recorded from the variety Kataribhog. The highest grain yield (2.54 t ha^{-1}) was obtained from Kataribhog and the lowest grain yield (1.83 t ha^{-1}) was obtained from Kalizara. Among the seven aromatic rice varieties under North-west condition Kataribhog and BRRI dhan34 are suitable in respect of yield.

An experiment was conducted by Chowdhury *et al*. (2016) with a view to finding out the effect of variety and level of nitrogen on the yield performance of fine aromatic rice. The experiment consisted of three varieties *viz*. Kalizira, Binadhan-13 and BRRI dhan34. Variety significantly influenced the yield of aromatic rice. The highest grain yield (3.33 t ha^{-1}) was obtained from Binadhan-13 followed by BRRI dhan34 (3.16 t ha^{-1}) and the lowest grain yield was found in Kalizira (2.11 t ha^{-1}).

Sarkar *et al*. (2014) conducted an experiment to study the yield and quality of aromatic fine rice as affected by variety and nutrient management. The experiment comprised three aromatic fine rice varieties *viz*. BRRI dhan34, BRRI dhan37 and BRRI dhan38. The tallest plant (142.7 cm), the highest number of effective tillers hill^{-1} (10.02), number of grains panicle^{-1} (152.3), panicle length (22.71cm), 1000-grain weight (15.55g) and grain yield (3.71 t ha^{-1}) were recorded in BRRI dhan34.

Roy *et al.* (2014) evaluated 12 indigenous *Boro* rice varieties where the plant height and tillers hill^{-1} at different DAT varied significantly among the varieties up to harvest. At harvest, the tallest plant (123.80 cm) was recorded in Bapoy and the shortest (81.13 cm) in GS. The maximum tillers hill^{-1} (46.00) was observed in Sylhety *Boro* and the minimum (19.80) in Bere Ratna. All of the parameters of yield and yield contributing characters differed significantly at 1% level except grain yield, biological yield and harvest index. The maximum effective tillers hill^{-1} (43.87) was recorded in the variety Sylhety *Boro* while

Bere ratna produced the lowest effective tillers hill^{1} (17.73). The highest (110.57) and the lowest (42.13) filled grains panicle^{-1} was observed in the variety Koijore and Sylhety *Boro,* respectively. Thousand grain weight was highest (26.35 g) in Kali *Boro* and the lowest (17.83 g) was in GS one. Grain did not differ significantly among the varieties but numerically the highest grain yield (5.01 t ha^{-1}) was found in the variety Koijore and the lowest in GS one (3.17 t ha^{-1}).

In 2014, Sarkar and Sarkar conducted an experiment to study the yield and quality of aromatic fine rice as affected by variety and nutrient management. The experiment comprised three aromatic fine rice varieties *viz*. BRRI dhan 34, BRRI dhan37 and BRRI dhan 38, and eight nutrient managements *viz*. control (no manures and fertilizers), recommended dose of inorganic fertilizers, cowdung at 10 t ha^{-1}, poultry manure at 5 t ha^{-1}, 50% of recommended dose of inorganic fertilizers + 50% cowdung, 50% of recommended dose of inorganic fertilizers + 50% poultry manure, 75% of recommended dose of inorganic fertilizers + 50% cowdung and 75% of recommended dose of inorganic fertilizers + 50% poultry manure. The tallest plant (142.7 cm), the highest number of effective tillers hill^{-1} (10.02), number of grains panicle^{-1} (152.3), panicle length (22.71cm), 1000-grain weight (15.55g) and grain yield (3.71 t ha^{-1}) were recorded in BRRI dhan 34. The highest aroma was found in BRRI dhan 37 and BRRI dhan 38. The highest number of effective tillers hill^{-1} (11.59), number of grains panicle^{-1} (157.6), panicle length (24.31 cm) and grain yield (3.97 t ha^{-1}) were recorded in the nutrient management of 75% recommended dose of inorganic fertilizers + 50% cowdung (5 t ha^{-1}). The treatment control (no manures and fertilizers) gave the lowest values for these parameters. The highest grain yield (4.18 t ha^{-1}) was found in BRRI dhan34 combined with 75% recommended dose of inorganic fertilizers + 50% cowdung, which was statistically identical with BRRI dhan 34 combined with 75% of recommended dose of inorganic fertilizers + 50% poultry manure and the lowest grain yield (2.7 t ha^{-1}) was found in BRRI dhan37 in control (no manures and fertilizers). The highest aroma was found in BRRI dhan 38 combined with 75% recommended dose of inorganic fertilizers + 50% cowdung.

Islam *et al*. (2013) conducted an experiment to study the yield and quality of aromatic fine rice as affected by variety and nutrient management. The experiment comprised three aromatic fine rice varieties viz. BRRI dhan34, BRRI dhan37 and BRRI dhan38. The tallest plant (142.7 cm), the highest number of effective tillers hill^{-1} (10.02), number of grains panicle^{-1} (152.3), panicle length (22.71cm), 1000-grain weight (15.55g) and grain yield (3.71 t ha^{-1}) were recorded in BRRI dhan34. The highest grain protein content (8.17%) was found in BRRI dhan34 whereas the highest aroma was found in BRRI dhan37 and BRRI dhan 38.

In 2012, Mannan *et al.* reported that the Badshabhog and Kalijira showed taller plants and Chinigura was shorter while Chinigura produced the greatest tillers at early, mid and at later growth stages and the lower tillers was observed in Badshabhog. Chinigura produced the highest amount of DM and while least amount of DM was observed in Kataribhog. The Chinigura showed late flowering and produced significantly the highest panicles but it was statistically identical with Kalijira, while, Kataribhog exhibited early flowering and lower number of panicles but number of grains panicle^{-1} was found more in Badshabhog. The heaviest grain hill^{-1} was found in Kataribhog while the light grain was observed in Badshabhog. The grain yield of Chinigura and Kalijira was almost identical. Lower grain yield was found in Kataribhog which may be attributed to the lower number of panicles and grain panicle^{-1}.

Sritharan and Vijayalakshmi (2012) evaluated the physiological traits and yield potential of six rice cultivars *viz.,* PMK 3, ASD 16, MDU 3, MDU 5, CO 47 and RM 96019. The plant height, total dry matter production and the growth attributes like leaf area index, crop growth rate and R:S ratio were found to be higher in the rice cultivar PMK 3 that showed significant correlation with yield. Yield and yield components like number of productive tillers, fertility co-efficient, panicle harvest index, grain weight and harvest index were found to be higher in PMK 3.

Panwar *et al.* (2012) studied to evaluate the performance of rice varieties. Growth parameters *viz.* plant height (cm), No. of tillers, leaf area index and dry matter accumulation (g) was highest in JGL-3844 over rest of varieties. The effective tillers m^{-2} (331.6), panicle length (25.63), grains $panicle^{-1}$ (68.23), sterility percent (12.1%), grain yield (60.9 q ha^{-1}) and straw yield (92.58 q ha^{-1}) yield were also highest in variety JGL-3844.

Fatema *et al.* (2011) evaluated forty five aromatic rice genotypes to assess the genetic variability and diversity on the basis of nine characters. Significant variations were observed among the genotypes for all the characters. Thousand grain weight have been found to contribute maximum towards genetic diversity in 45 genotypes of aromatic rice.

Islam (2011) conducted a field experiment at BINA, Mymensingh with five aromatic rice genotypes *viz*., BRRIdhan34, Ukunimadhu, RM-100/16, KD5 18-150 and Kalozira by at BINA, Mymensingh. Among the varieties, KD5 18-150 showed late maturity and higher grain yield, total dry matter $plant^{-1}$ and harvest index under temperature stress.

Baset Mia and Shamsuddin (2011) reported that the aromatic rice cultivars showed tallest plant stature, profuse tillers $hill^{-1}$, panicle $hill^{-1}$ and larger panicle but smaller grain, higher grain yield, lowest straw yield and harvest index compare modern rice. Modern rice cultivars generally had higher TDM, LAI, LAR, CGR, RGR whereas aromatic cultivars resulted in higher NAR. The highest grain yield of modern rice cultivars was due to the higher harvest index. Poor yield in aromatic rice cultivars was due to lower translocation of assimilates.

Jeng *et al.* (2009) found that the cultivar Tainung 67 had greater yield (7.2 mg ha^{-1}) than SA419 (6.2 mg ha^{-1}). The greater yield of SA419 than Tainung 67 in autumn was due to its higher net assimilation rate and better dry matter partitioning during grain filling. Significant panicle branch effects on the distribution pattern of grain weight were also found between Tainung 67 and SA419 with greater variation for the former than the latter.

Hossain *et al*. (2008) conducted the study to observe the yield and quality of ten popular aromatic rice varieties of Bangladesh. The varieties were Kataribhog (Philippines), Kataribhog (Deshi), Badshabhog, Chinigura, Radhunipagal, Kalizera, Zirabhog, Madhumala, Chiniatab and Shakhorkora. All the yield contributing attributes and quality parameters varied significantly among the aromatic rice varieties. The highest grain yield was obtained from Kataribhog (Philippines) which identically followed by Badshabhog. In respect of quality, Zirabhog gave the highest head rice outturn that was statistically similar to Badshabhog and Chiniatab. All the tested varieties had bold type shape. Grain protein content ranged from 6.6-7.0 % in brown rice. The cooking time of tested varieties varied from 12 to 16 minutes. Aroma intensity differed due to variety. Kalizera, Badshabhog, Chiniatab contained high level of aroma while, rests of the varieties had moderate type aroma.

Masum *et al.* (2008) reported that that Nizershail produced the taller plant height than BRRI dhan44 at different DAT. Total tillers hill^{-1} was significantly influenced by variety at all stages. At 30 and 60 DAT, Nizershail had significant by higher amount of DM (35.46% higher at 30 DAT and 18.01% higher at 60 DAT) than BRRI dhan44 but at harvest BRRI dhan44 had significantly higher amount of DM (39.85 g hill^{-1}) that was 18.42% higher than Nizershail. BRRI dhan44 produced higher (4.85 t ha^{-1}) grain yield than Nizershail (2.46 t ha^{-1}). Nizershail produced higher (7. 22 t ha^{-1}) straw yield compared to BRRI dhan44 (6.34 t ha^{-1}).

Khan *et al*. (2006) reported that the variety Rachna showed the highest yield of 4009.590 kg ha^{-1} followed by Basmati-385, Shaheen and Super with the production of 3678.983, 2939.257 and 2175.303 kg ha^{-1}, respectively. However, the plant height (cm) of Rachna was at 2nd position (125.400 cm) after Basmati-385 at 129.767 cm. The maximum tiller plant^{-1} (18) was obtained by variety Rachna, which significantly differ from variety Super that produced 10 tillers plant^{-1}. The maximum spike plant^{-1} (18) were shown by variety Rachna and the number of tiller plant^{-1} produced by Rice variety Basmati-385 i.e., 17. The highest yield of Rachna variety was due to the best performance in terms of tillers plant^{-1}, spike plant^{-1} and weight of 1000 grains.

George *et al.* (2005) evaluated the 12 aromatic rice varieties/cultivars where pooled analysis of the yield data indicates that 'Pusa Basmati-1' had the highest grain yield of 2777 kg ha^{-1}. But it was statistically at par with that of 'Jeerakasala' (2743 kg ha^{-1}) and IET-12606 (2610 kg ha^{-1}), implying the suitability of these three varieties for cultivation in Wayanad district.

2.2 Effect of fertilizer management on lodging resistance of rice cultivars

In 2020, Zhang *et al*. set up a pot experiment and a field experiment with giant rice varieties Feng5 and Feng6 under five doses of nitrogen fertilizers, namely, 0 kg ha^{-1} (CK), 75 kg ha^{-1} (T_1), 150 kg ha^{-1} (T_2), 225 kg ha^{-1} (T_3) and 300 kg ha^{-1} (T_4). The parameters such as leaf area index (LAI), lodging index (LI), nitrogen utilization rate, photosynthesis rate and grain yield were measured. The results showed that with the increase of nitrogen dose in a certain range, LAI, plant height, the number of tillers, net photosynthetic rate (NPn), the transpiration rate (Tr), and the grain yield increased while the lodging index (LI), the nitrogen agronomic utilization rate (AE) and nitrogen partial productivity (PFPN) decreased. Additionally, with the increase of nitrogen application, the grain yield index (HI) and nitrogen contribution rate (FCRN) of rice presented a parabolic trend.

Pan *et al*. (2019) stated that improved nitrogen management can enhance lodging resistance and lower internodes play a key role in the lodging resistance of rice. However, little is known about the cellular and molecular mechanisms underlying the enhanced lodging resistance under improved nitrogen management. In the present study, two rice varieties, with contrasting lodging resistance, were grown under optimized N management (OPT) and farmers' fertilizer practices. Under OPT, the lower internodes of both cultivars were shorter but the upper internodes were longer, while both culm diameter and wall thickness of lower internodes were dramatically increased. Microscopic examination showed that the culm wall of lower internodes under OPT contained more sclerenchyma cells beneath epidermis and vascular bundle sheath. The genome-wide gene expression profling revealed that transcription of genes encoding cell wall loosening factors was down-regulated while transcription of genes participating in lignin and starch synthesis was up-regulated under OPT, resulting in inhibition of longitudinal growth, promotion in transverse growth of lower internodes and enhancement of lodging resistance. This is the frst comprehensive report on the morpho-anatomical, mechanical, and molecular mechanisms of lodging resistance of rice under optimized N management.

Islam *et al*. (2017) conducted an experiment with a view to examining the effect of soil and foliar application of silicon on the lodging resistance, growth and yield of selected aromatic rice varieties. Two rice varieties (Kalizira and Binadhan-13) were evaluated under four rates of silicon with two application methods. Silicon rates were 0, 200, 400 and 600 Kg ha^{-1}.Two application methods, soil and foliar spray, were evaluated for each silicon rate. Soil applications were made just prior to planting. Foliar sprays were made at vegetative, reproductive and ripening growth stage. At 45 DAT, the chlorophyll content was 31.1 and 30.1 at Binadhan-13 and Kalizira, respectively. However, at 105 DAT it was 32.1 and 30.0 at Binadhan-13 and Kalizira, respectively. The results showed that the highest grain yield (3.01 t ha^{-1}) was obtained by Binadhan-13 followed by Kalizira which produced 2.69 t ha^{-1}. Method of fertilizer application showed that highest grain yield (3.04 t ha^{-}

^{1}) was produced in soil incorporation method and the second highest yield (2.65 t ha^{-1}) in foliar application method In case of silicon rates, 600 Kg ha^{-1} silicon showed highest chlorophyll content in leaves and produced the highest grain yield (3.06 t ha^{-1}) due to the maximum number of total tiller $hill^{-1}$ (8.40) and number of filled grain $panicle^{-1}$ (169.9) followed by 400 Kg ha^{-1} silicon (2.97 t ha^{-1}), 200 Kg ha^{-1} silicon (2.77 t ha^{-1}) and lowest by control (2.59 t ha^{-1}). Interactions between varieties, method and silicon rates showed that the highest grain yield in soil incorporation method with 600 Kg ha^{-1} silicon by Binadhan-13 (3.59 t ha^{-1}).

Cuong *et al*. (2017) reported that application of silicon (Si) could greatly boost rice yield and mitigate abiotic stress and conducted a field experiment to evaluate the effects of five different combined doses of standard fertilizer practice and Si fertilizer on growth, yield and yield components, as well as nutrient uptake of rice. The treatments consisted of the recommended dose of fertilizer (RDF, 110 kg/hm^2 N + 90 kg/hm^2 P_2O_5 + 80 kg/hm^2 K_2O) as the control, RDF + 100 kg/hm^2 SiO_2, RDF + 200 kg/hm^2 SiO_2, RDF + 300 kg/hm^2 SiO_2 and RDF + 400 kg/hm^2 SiO_2. The results showed that the growth, grain and straw yields as well as yield components (number of grains per panicle, seed-setting rate and 1000-grain weight) were significantly affected by Si application. The highest grain yield of 3705 kg/hm^2 was obtained with the highest level of Si fertilizer in combination with RDF (RDF + 400 kg/hm^2 SiO_2), however, it was statistically at par with the yields obtained with RDF + 300 kg/hm^2 SiO_2 (3664 kg/hm^2) and RDF + 200 kg/hm^2 SiO_2 (3 621 kg/hm^2). The optimum dose of Si fertilizer with maximized grain yield (3716 kg/hm^2) was 329 kg/hm^2 SiO_2. Si application at the level of 329 kg/hm^2 along with RDF would help in the sustainable production of rice.

Girija-Rani *et al*. (2017) reported that lodging of the rice crop is the major limiting factor to rice productivity in cyclone prone areas. Lodging not only reduces the yield but also it deteriorates grain quality impedes mechanical harvesting, increases harvesting and drying costs. Lodging resistance is complex trait influenced by environment and structural properties of the stem. Factors like cultivar, fertilizers application, irrigation, plant density, pest and disease management influences lodging apart from weather parameters. Though semi dwarf gene reduced lodging to certain extent but it resulted in yield plateau and also high yielding semi dwarf rice varieties like Swarna prone to lodging because of weak culm. Breeding for lodging resistant rice varieties is important strategy to combat adverse effects of climatic changed conditions. Direct selection for lodging resistance by visual score in segregating material is herculean task as it is influenced by structural properties of the stem and weather parameters. Type of lodging decides selection of traits suitable for lodging resistance. Stem lodging is the main type of lodging limits the rice productivity in irrigated ecosystem. Root lodging prevails under direct seeded condition where root anchorage is poor. Selection suitable phenotypic traits and genotyping with suitable molecular markers would help in framing suitable breeding strategy for the development of lodging resistant rice varieties.

Alvarez-Herrera *et al*. (2017) evaluated the effect of different doses and application times of a fertilizer with silicon on a rice crop, Fedearroz 50 variety. The experimental design was completely randomized with a 2×5 factorial arrangement. The first factor was dose (20 and 40 kg ha^{-1}) and the second factor was combination of period and application dose (100% preplant, 50% preplant + 50% first fertilization, 100% first fertilization, 50% preplant +50% second fertilization, 100% second fertilization) for a total of 10 treatments that were applied in 2 locations (Ibague and El Guamo). The preplant fertilizer applications increased the production of root biomass throughout the crop cycle and that the biomass of the stems and leaves had a similar behavior with the two doses of silicon. The tillering in Ibague presented a value of 520 clusters m^{-2}, 127% higher than in El Guamo, which had a value of 229 clusters m^{-2}, a highly significant difference. Throughout the period, height showed a behavior model double logistic sigmoid; the height of the rice plants was higher in El Guamo. In the two localities, Ibague and El Guamo, the most appropriate fertilizer dose of silicon was 20 kg ha^{-1} in the second fertilization.

Mactal and Canare (2016) conducted two experiments during the wet season to determine the effects of paclobutrazol and nitrogen on the lodging resistance, agro-morphological characteristics and yield performance of two traditional rice varieties; Elon-elon and Palawan Red. Palawan red had the longest first and fourth internodes, more unfilled spikelets per panicle, heavier 1000 grains weight and higher leaf area index than Elonelon. On the other hand, smaller stem diameter, more productive tillers and grain weight per hill and longer panicles were obtained from Elon-elon than Palawan red. Apparently, Palawan red had longer first, second and third internodes, more unfilled spikelets per panicle, heavier 1000 grain weight and higher leaf area index than Elon-elon. Applications of 30 and 60 kg N per ha had significantly higher lodging index than the untreated plants. Harvest index and grain yield were lowest in plants applied with 30 and 60 kg N per ha, attributable to high lodging index. Culm strength was reduced by high rates of nitrogen causing significant increase in lodging index. The time of lodging is crucial in predicting the yield performance of the plants.

Wu-jun *et al*. (2016) conducted field experiments using two japonica rice varieties Wuyunjing23 (lodging-resistance variety) and W3668 (lodging-susceptible variety) with three top-dressing N fertilizer rates (0, 135 and 270 kg N ha^{-1}) in 2013 and 2014 to determine the mechanism of lodging resistance in japonica rice as affected by carbohydrate components, especially its related arrangement in culm tissue. Lodging related physical parameters, morphological characteristics and stem carbohydrate components were investigated at 30 days after full heading stage. Results showed that with increasing N fertilizer rates, the lodging rate and lodging index increased rapidly primarily due to significant reduction of breaking strength in two japonica rice varieties. Correlation analysis revealed that breaking strength was significantly and positively correlated with bending stress, but negatively correlated with section modulus, except for significant correlation at W3668 in 2014. With higher N fertilizer rate, the culm wall thickness was almost identical, and culm diameter increased slightly. The structural carbohydrates, especially for lignin content in culm, reduced significantly under high N rate. Further revealed that high N treatments were consistent with reduction of bending stress, especially for W3668 and thus, resulted in poor stem strength and higher lodging index.

Zhang *et al*. (2016) reported that lodging in rice production often limits grain yield and quality by breaking or bending stems. Excessive nitrogen (N) fertilizer rates are the cause of poor lodging resistance and late maturity in rice, but little is known about the effect of top-dressing N application rates on the mechanical strength of japonica rice plants, especially how the anatomical structure in culms is affected by N. They conducted a field experiments on two japonica rice varieties with three top-dressing N application rates, 0 kg N ha^{-1} (LN), 135 kg N ha^{-1} (MN), and 270 kg N ha^{-1} (HN) as urea. Wuyunjing23, a lodging-resistant japonica rice cultivar and W3668, a lodging-susceptible japonica rice cultivar were used. The lodging index, breaking strength, morphological and anatomical traits in culms were measured in this study. The higher lodging index of rice plants was primarily attributed to the weak breaking strength of the lower internodes. The longer elongated basal internodes were responsible for higher plant height and a higher lodging index. Correlation analysis showed that breaking strength was significantly and positively correlated with the thickness of the mechanical tissue but was significantly and negatively correlated with the inner diameter of the major axis (b2). The plant height, inner diameter of the minor axis (a2) and b2 increased significantly, but the area of the large vascular bundle (ALVB) and the area of the small vascular bundle (ASVB) decreased significantly and resulted in lower stem strength and a higher lodging index under higher top-dressing N conditions. The culm diameter of the W3668 cultivar increased slightly with no significant difference, and the sclerenchyma cells in the mechanical tissues and vascular bundles showed deficient lignifications under high top-dressing N conditions. Moreover, the ALVB and the ASVB decreased significantly, while the area of air chambers (AAC) increased rapidly. An improvement in the lodging resistance of japonica rice plants could be achieved by reducing the length of the lower internodes, decreasing the inner culm diameter and developing a thicker mechanical tissue. Top-dressing N application increased the plant height and inner culm diameter and decreased the ALVB and the ASVB of the Wuyunjing23 cultivar and caused deficient lignified sclerenchyma cells, lowered the ALVB and the ASVB, and increased the AAC of the W3668 cultivar resulting in weaker stem strength and a higher lodging index.

Salman *et al*. (2012) carried out an experiment with nitrogen rates (0, 50, 100 and 150 kg N ha^{-1}) applied as urea and silicon rates (0, 300 and 600 kg ha^{-1}) applied as calcium silicate. Results showed that minimum of the plant height, flag leaf length, fourth inter-node bending moment and grain yield (4350 kg ha^{-1}) were obtained at N_0, as well as the maximum of the plant height, panicle length, flag leaf length, third inter-node length were observed at N_{100} and N_{150}, respectively. But the highest of bending moment obtained for fourth inter-node and maximum grain yield (6063 kg ha^{-1}) was observed in N_{150}. Treatment Si_{600} had increased significantly over control in plant height, stem length, panicle length, third inter-node length, third inter-node bending moment, cellulose, hemi-cellulose and lignin in relation to 7.76, 9.91, 30.18, 31.03, 18.71, 7.60, 34.50 and 26.26 %, respectively. Therefore treatment with N_{150} and Si_{600} had shown best results for agronomical indices and grain yield.

Ming-Cong *et al*. (2010) conducted a field experiment to elucidate the mechanism underlying the lodging resistance of rice plant in cold area with 4 nutrition managements and the physical properties, mechanical features and carbon-nitrogen ratio of the stems of rice were analyzed. The yield of the farmers fertilization practice (FFP) was 8.55 t hm^{-2}. Optimal fertilization practice (OPT) increased the yield, reduced the length of the first and second internode of the basal stem by 11.6% (*P*<5%), 13% and 6% (*P*<5%), respectively, significantly increased carbon-nitrogen ratio, stem diameter, stem wall thickness, leaf sheath weight and area of cross section 30 d after heading, and reduced the index of lodging resistance by 14.18% (*P*<5%). Compared to FFP, the yield of the farmers fertilization practice for high yield (FFP-H) was increased by 15.2% and achieved high-yield rice. Compared to FFP-H, the optimal fertilization practice for high yield (OPT-H) increased rice yield by 7.4%, the length of the first and second internode of the basal stem is reduced by 12% and 4% (*P<5%*), separately, at the same time, carbon-nitrogen ratio, stem diameter, stem wall thickness, leaf sheath weight and area of cross section were significantly increased, and the index of lodging resistance was reduced by 6.19% (*P<5%*) 30 days after heading. Compared to OPT, the harvest panicles of OPT-H was increased by 15.1% (*P<5%*), yield was increased by 10.9% (*P<5%*), but the index of lodging resistance between the two treatments was not significantly different. Conclusion: OPT and OPT-H increased the height of gravity center and plant height, but reduced the distance of basal internode due to optimization of internode collocation of rice, and increased carbon-nitrogen ratio of rice stems and stem diameter, promoted stem substantiality, resulting in high grain yield and lodging resistance of rice plant.

Shahidullaha *et al*. (2009) conducted a research work with 10 rice germplasm to assess the different lodging concerned parameters and their interrelationships. A great extent of diversity among aromatic rice genotypes was observed in respect to canopy architecture and lodging related characters. Minimum seedling height was 30 cm for BR39 and the maximum was 47 cm for Hatisail. Variations were found in the cultivars regarding penultimate and flag leaf angles and dimensions of both the leaves. Maximum plant height was recorded to be 153 cm in Baoi jhak and the minimum was 100 cm in BR28. The longest panicle was observed in Nizersail (27 cm) and shortest in Hatisail (21 cm). The range of culm diameter was 4.0–4.7 mm and culm thickness was 0.40–0.51 mm. Rice cultivars varied for bending moment from 812 g cm

(BR28) to 2263 g cm (Doiar guro). Lodging index was at a minimum 2.7 in BR28 and a maximum 11.28 in Sugandha-1. Plant height exhibited positive correlation with panicle exertion and internode lengths, and hence lodging index. Lodging index was found to have a negative relationship with breaking strength. In path analysis, bending moment projected highest positive direct effect on lodging index.

Duy *et al*. (2004) carried out field experiments in 2001 and 2002 to examine the lodging-resistance characteristics of various rice cultivars bred including the widely-cultivated cultivars (WCC) and the newly-released cultivars (NRC). The lengths of the lower internodes and culms were often shorter in NRC than in WCC. Bending moment by whole plant was not different between NRC and WCC, but the breaking strength at the basal internode (IV) with leaf sheaths was often larger in NRC than in WCC. As a result, the lodging index was smaller in the former than in the latter. Breaking strength at the basal internode (IV) without leaf sheaths was also often larger in NRC than in WCC due to a larger cross section modulus or bending stress in NRC. Although the lengths of the upper internodes (I+II+III) were not different between BNo and CONT, the lower internodes (IV+V) were shorter in BNo, resulting in the shortened culms in BNo, especially in the long-culm cultivars. Breaking strength at the basal internode (IV) with leaf sheaths was significantly larger in BNo than in CONT, and thus the lodging index was smaller in BNo. The breaking strength at the basal internode (IV) without leaf sheaths and its two components, cross section modulus and bending stress, were also significantly larger in BNo than in CONT, particularly in the long-culm cultivars. These results suggest that besides creating new cultivars with short and stiff lower internodes, cultivation with sparse planting density accompanied with application of a small amount of nitrogen fertilizer in the early growth stage like BNo may also effectively increase the lodging resistance in rice plants.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted in the Experimental Field of Department of Agricultural Botany, Sher-e-Bangla Agricultural University (SAU) at *Boro* season, 2019-2020.

3.1 Experimental location

The location of the Experimental site is 90°33′ E longitude and 23°77′N latitude with an elevation of 8.2 m from sea level. Location of the experimental site presented in Appendix I.

3.2 Soil

The characteristics of the soil under the experimental plot were analyzed in the Soil Testing Laboratory, SRDI, Khamarbari, Dhaka. The details of morphological and chemical properties of initial soil of the experiment plot were presented in Appendix II.

3.3 Climate

Details on the meteorological data of air temperature, relative humidity, rainfall and sunshine hour during the period of the experiment was collected from the Weather Station of Bangladesh, Sher-e-Bangla Nagar, presented in Appendix III.

3.4 Plant material

Three traditional aromatic rice cultivars *viz*. Badshabhog, Chiniatab (awnless) and Kataribhog (awnless) were used in this study.

3.5 Plan of action

Seeds of aforementioned cultivars were used from own collection (Departmental Germplasm). Field experiment was carried out within November, 2019 to May, 2020.

3.6 Experimental design, layout and cultural management

The experiment consists of two factors RCBD.

Factor A: Variety

i) Badshabhog

ii) Chiniatab (awnless)

iii) Kataribhog (awnless)

Factor B: Fertilizer management

i) T_1 = {30 (BS) + 20 (MT) + 10 (BPI)} kg ha^{-1} + no silicon and cow-dung

ii) T_2 = {30 (BS) + 20 (MT) + 10 (BPI)} kg ha^{-1} + silicon (450 SiO_2 kg ha^{-1}) + no cow-dung

iii) T_3 = {30 (BS) + 20 (MT) + 10 (BPI)} kg ha^{-1} + No silicon + cow-dung (6 t ha^{-1})

iv) T_4 = {30 (BS) + 20 (MT) + 10 (BPI)} kg ha^{-1} + silicon (450 SiO_2 kg ha^{-1}) + cow-dung (6 t ha^{-1})

**BS= basal dose; MT= mid-tillering and BPI= before panicle initiation*

The treatments were distributed following randomized complete block design and replicated thrice. Unit plot size was 4 m × 2.5 m (10 m^2). A buffer (ails or levee) of 0.5 m and 1.0 m was maintained in between unit plots and blocks, respectively (Layout is presented in Appendix IV). Seeds of afore-mentioned three cultivars were sown in the first-second week of November, 2019 so that the seedlings receive induction of short day length. Then thirty days old seedlings were transplanted in the experimental plots in mid-December, 2019 maintaining 20 × 15 cm spacing with one healthy seedling $hill^{-1}$. Fertilizers were applied @ 60-50-40-10-4 kg N, P_2O_5, K_2O S and Zn ha^{-1} (BRRI, 2013). All fertilizers including half amount of urea were applied as basal during final land preparation. Rest of urea was top-dressed in two splits at mid-tillering and at 4-5 days before panicle initiation stages. Cow-dung and silicon were applied according to treatments.

Proper intercultural operations were done to ensure the normal growth of the crops. Seedlings in some hills, if die off, then these were replaced by new one within one week of transplanting with seedlings from the respective source. The plot was irrigated whenever require. Weeding was done as and when necessary. Plant protection measures *viz.* insecticide and fungicide were sprayed as require to keep the crop free from insect and pathogen attack.

3.7 Data Collection

Data were recorded on plant height, tillers number, leaf area index, flag leaf chlorophyll content, lodging parameters, lodging severity, days to flowering, days to maturity, source-sink relation, aroma quality, yield and yield components.

3.8 Sampling for data collection

Data pertaining to leaf area were taken through destructive sampling method. Five sample hills were uprooted from each plot at heading and roots were removed. Hills were selected from third rows during sampling to minimize the border or side effect.

3.9 Details of data recording

3.9.1 Plant height

Plant height was measured from five selected hills of each plot at flowering stage.

3.9.2 Tiller numbers

Tillers number was measured from five selected hills of each plot at flowering stage.

3.9.3 Leaf area index

Then uprooted plant hills were partitioned into green leaf, dead leaf, stem (culm + leaf sheath) and panicles. Green leaf area (LA) was measured by a leaf area meter just after removal of leaves to avoiding rolling and shrinkage and transformed into leaf area index (LAI) according to Yoshida (1981).

3.9.4 Lodging parameters

Culm characters related to lodging were determined at 25 days after heading. Three representative hills were sampled from each plot and 12 largest tillers, 4 from each hill was used to measure characters related to lodging. Culm height (length from plant base to panicle neck node), internodes number and length of first (N_1), second (N_2) third (N_3) and fourth (N_4) internodes from the top were measured. The culm dry weight cm^{-1} from N_3 internode was calculated. Fresh weight of the N_1 and N_2 with leaf and leaf sheath were measured. The diameter of the fourth (W_3) internodes was also measured.

Lodging severity at maturity was scored visually on a scale of 1 to 9, where 1 was totally upright and 9 was totally lodged. Occurrence of lodging in each plot was recorded in relation to days after flowering.

3.9.5 Estimation of Chlorophyll content in flag leaf

Flag leaves were sampled from 5 plants at flowering stage and a segment of 20 mg from middle portion of flag leaf was used for chlorophyll content estimation on fresh weight basis extracting with 80% acetone and for that double beam spectrophotometer (Model: U-2001, Hitachi, Japan) were used according to Witham *et al*. (1986).

Amount of chlorophyll were calculated using following equations/formula

$$\text{Chlorophyll a (mg/g)} = [12.7(OD_{663})-2.69\ (OD_{645})] \times \frac{V}{1000\ W}$$

$$\text{Chlorophyll b (mg/g)} = [22.9(OD_{645})-4.68\ (OD_{663})] \times \frac{V}{1000\ W}$$

$$\text{Chlorophyll a+b (mg/g)} = [20.2(OD_{645})-8.02\ (OD_{663})] \times \frac{V}{1000\ W}$$

Where, OD = Optical density regarding of the chlorophyll extract at the specific indicated weave length.

V = Final volume of the 80% acetone chlorophyll extract (ml)

W = Fresh weight in gram of the tissue extracted.

3.9.6 Source –sink relation

Ratio of spikelets number to leaf area and yield sink to leaf area reflect source efficiency. Ratio of spikelets number to leaf area (at heading) and yield sink to leaf area (at heading) were estimated as follows (Zhao *et al.,* 2006).

$$\text{Ratio of spikelets no to LA } (cm^{-2}) = \frac{\text{Spikelets number } cm^{-2}}{\text{LAI at heading}}$$

$$\text{Ratio of yield sink to LA } (mg\ cm^{-2}) = \frac{\text{Yield sink } mg\ cm^{-2}}{\text{LAI at heading}}$$

3.9.7 Days to flowering

It was recorded from date of seeding to the day when at least 75-80% plant flowered.

3.9.8 Days to maturity

It was recorded from date of seeding to maturity when at least 75-80% grain golden in colour or filled properly.

3.9.9 Yield components

Five hills were selected at random in each plot other than those from the $5m^2$ undisturbed areas. The tiller which has at least one grain $panicle^{-1}$ considered as effective one. 20 panicles from those hills were threshed. Grain and sterile spikelets were separated by a seed sorter. After separation, the grains and sterile spikelets were counted by an automatic counter and then grain $panicle^{-1}$, sterile spikelets $panicle^{-1}$, total spikelets $panicle^{-1}$ and spikelets sterility (%) was calculated.

3.9.10 Grain yield

Grain yield was recorded from the central 5 m^2 area of each unit plot and was adjusted to 14% moisture content.

3.9.11 Straw yield

The weight of straw of harvested area ($5m^2$ undisturbed sample areas) per plot was recorded after drying.

3.9.12 Biological yield

Grain yield and straw yield were altogether regarded as biological yield.

Biological yield (BY) = Grain yield + straw yield

3.9.13 Harvest Index (HI)

HI is the ratio of economic yield to biological yield. It was calculated using following formula-

$$HI (\%) = \frac{\text{Grain yield}}{\text{Biological yield}} \times 100$$

3.9.14 Grain aroma test

Forty grains of each cultivar were soaked in 10 ml 1.7% KOH solution at room temperature in a covered glass petri-plate for about 1 hour. The sample was scored on 0-3 scale with 0, 1, 2 and 3 corresponding to absence of aroma, slight aroma, moderate aroma, and strong aroma, respectively. The five panels of students and staffs were invited to score the aroma in each cultivar.

3.10 Statistical Analysis

The data obtained for different characters were statistically analyzed to observe the significant difference among different aromatic rice varieties. The analysis of variance of all the recorded parameters performed using MSTAT-C software. The difference of the means value was separated by Least Significant Difference (LSD) Test at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

The study was conducted to study the effect of nitrogen, silicon and organic fertilizer management on growth, yield and lodging of traditional aromatic rice. Analyses of variance (ANOVA) of the data on different growth, yield parameters, yield and nutrients content of tomato are presented in Appendix V-XI. The results have been presented and discusses with the help of table and graphs and possible interpretations given under the following headings:

4.1 Growth parameters

4.1.1 Plant height

Effect of variety

Plant height difference among the varieties of rice was significant (Appendix V). The highest plant height (103.90 cm) was recorded from the variety V_1 (Badshabhog) followed by V_3 (Kataribhog) whereas the lowest plant height (94.47 cm) was recorded from the variety V_2 (Chiniatab) (Figure 1). Variation in plant height among the varieties might be cause of genetical character. Supported result was also observed by Shahidullaha *et al*. (2009) who found variation in plant height among the varieties. Rashid *et al*. (2017) and Sarkar *et al*. (2014) also found significant variation among different rice varieties on plant height.

Effect of fertilizer management

Different treatments of fertilizer management showed significant variation on plant height of rice (Appendix V). Result revealed that the highest plant height (104.40 cm) was recorded from the treatment T_4 which was significantly different from other treatments followed by T_2, whereas the lowest plant height (94.00 cm) was recorded from the control treatment T_1 (Figure 2). In this study,

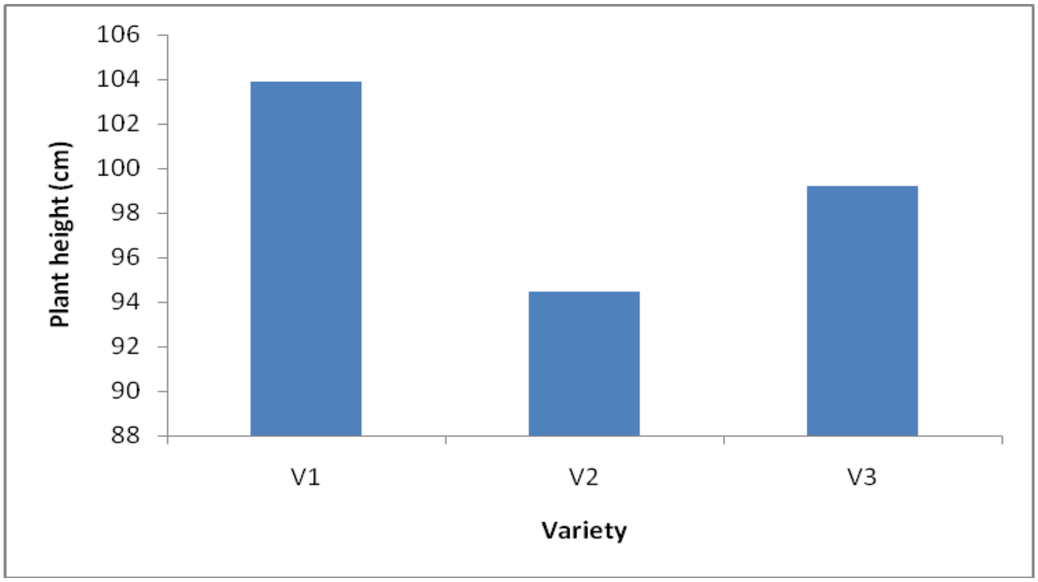

Figure 1. Plant height of rice as influenced by different varieties

V_1 = Badshabhog, V_2 = Chiniatab, V_3 = Kataribhog

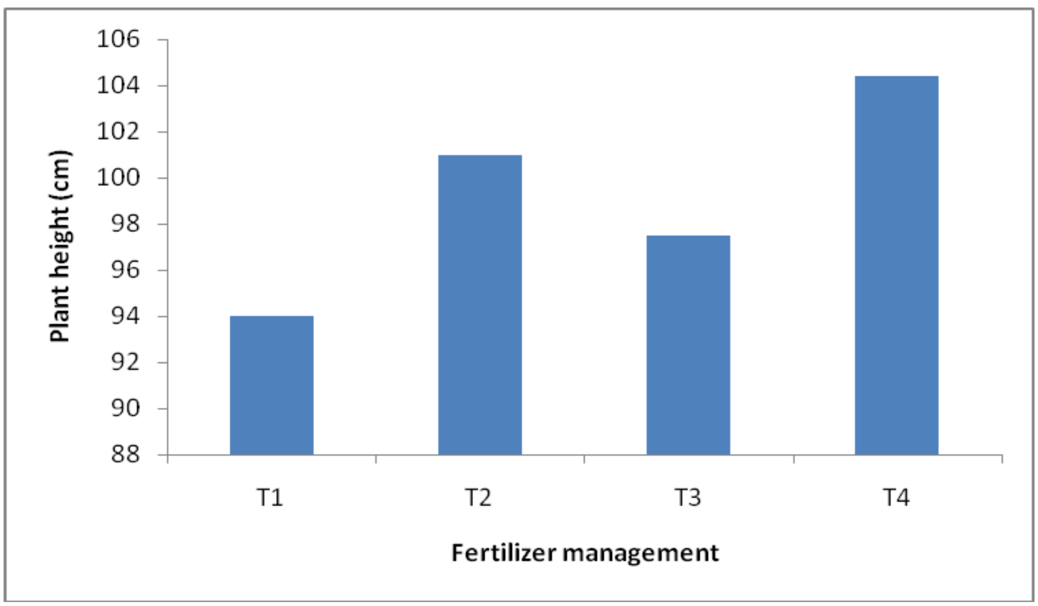

Figure 2. Plant height of rice as influenced by different fertilizer management

T_1 = {30(BS*) +20 (MT) + 10 (BPI)} kg ha^{-1} + no silicon and cow-dung, T_2 = {30(BS) +20 (MT) + 10 (BPI)} kg ha^{-1} + silicon (450 SiO_2 kg ha^{-1}) + no cow-dung, T_3 = {30(BS*) +20 (MT) + 10 (BPI)} kg ha^{-1} + No silicon + cow-dung (6 t ha^{-1}), T_4 = {30(BS) +20 (MT) + 10 (BPI)} kg ha^{-1} + silicon (450 SiO_2 kg ha^{-1}) + cow-dung (6 t ha^{-1})

**BS= basal dose; MT= mid-tillering and BPI= before panicle initiation*

plant height was increased by the application of Si. Pati *et al*. (2016) also reported an increase in plant height with the addition of Si fertilizer over the control. Salman *et al*. (2012) also found Treatment of Si_{600} had increased significantly over control in plant height.

Combined effect of variety and fertilizer management

Different treatment combinations showed significant difference on plant height (Appendix V). Results indicated that the treatment combination of V_1T_4 showed the highest plant height (108.50 cm) which was significantly different from other treatment combinations followed by V_1T_2. The lowest plant height (90.14 cm) was recorded from the treatment combination of V_2T_1 which was significantly different from other treatment combinations (Figure 3).

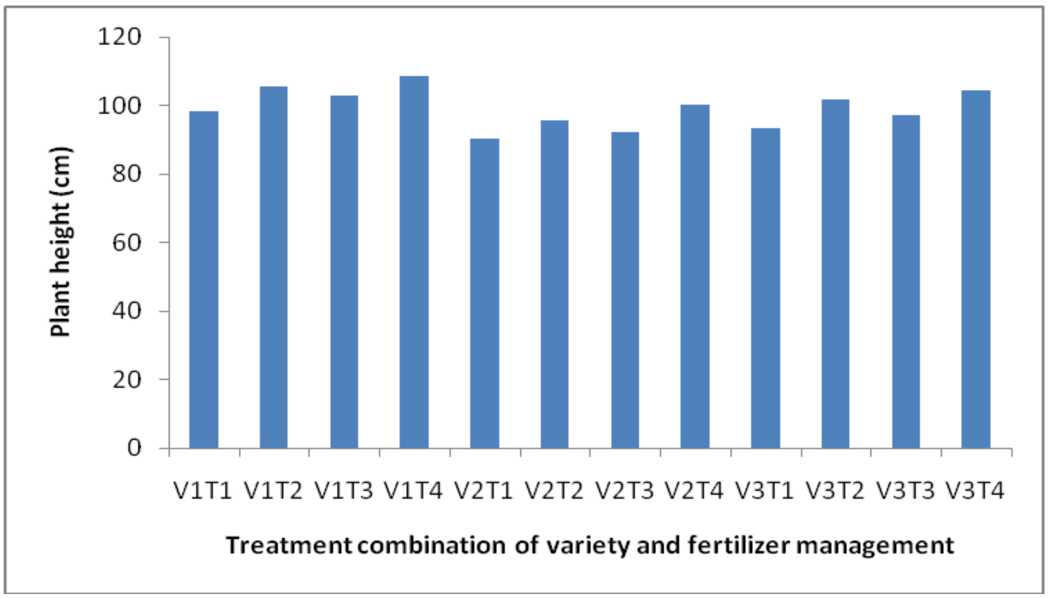

Figure 3. Plant height of rice as influenced by combined effect of different variety and fertilizer management

V_1 = Badshabhog, V_2 = Chiniatab, V_3 = Kataribhog

T_1 = {30(BS*) +20 (MT) + 10 (BPI)} kg ha^{-1} + no silicon and cow-dung, T_2 = {30(BS) +20 (MT) + 10 (BPI)} kg ha^{-1} + silicon (450 SiO_2 kg ha^{-1}) + no cow-dung, T_3 = {30(BS*) +20 (MT) + 10 (BPI)} kg ha^{-1} + No silicon + cow-dung (6 t ha^{-1}), T_4 = {30(BS) +20 (MT) + 10 (BPI)} kg ha^{-1} + silicon (450 SiO_2 kg ha^{-1}) + cow-dung (6 t ha^{-1})

**BS= basal dose; MT= mid-tillering and BPI= before panicle initiation*

4.1.2 Number of tillers hill^{-1}

Effect of variety

There was a significant variation on number of tillers hill^{-1} among the varieties of rice (Appendix V). It was found that the variety V_1 (Badshabhog) showed the highest number of tillers hill^{-1} (19.25) followed by V_2 (Chiniatab) whereas variety V_3 (Kataribhog) showed the lowest number of tillers hill^{-1} (16.67) (Figure 4). Sarkar *et al*. (2014) and Roy *et al.* (2014) also found similar results who found significant variation on number of tillers hill^{-1} due to varietal difference.

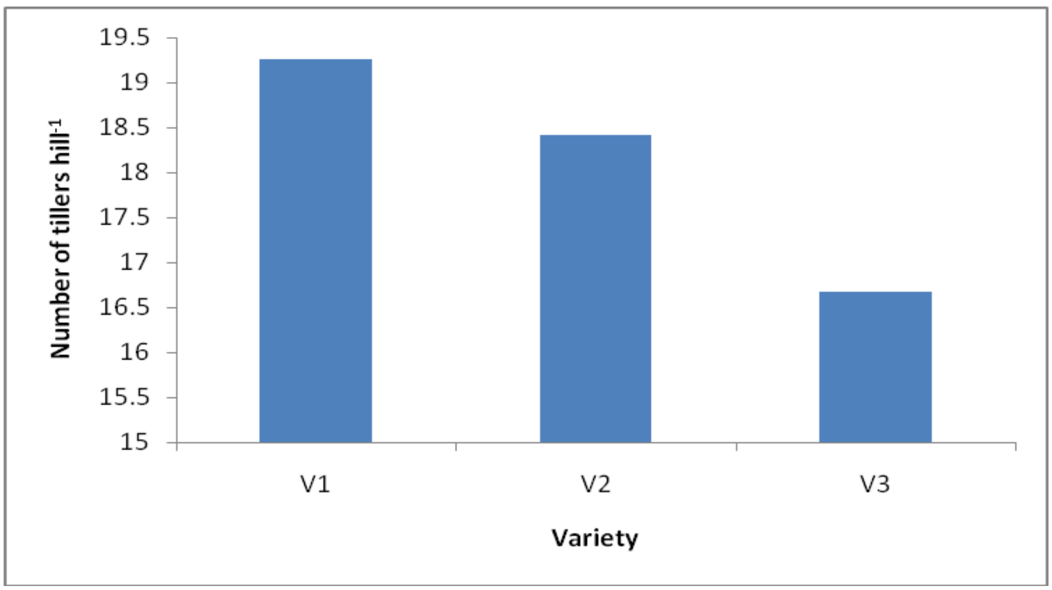

Figure 4. Number of tillers hill^{-1} as influenced by different varieties of rice

V_1 = Badshabhog, V_2 = Chiniatab, V_3 = Kataribhog

Effect of fertilizer management

Significant difference was recorded among the treatments of fertilizer management regarding number of tillers hill^{-1} (Appendix V). Figure 5 showed that the highest number of tillers hill^{-1} (21.56) was recorded from the treatment T_4 followed by the treatment T_2 whereas the control treatment T_1 showed the lowest number of tillers hill^{-1} (14.58). Grain yield of rice is dependent on tillering capacity as it is closely associated with panicle number per unit area

(Efisue *et al*., 2014). In the present study, number of tillers per hill was significantly increased with the application of Si fertilizer. Our findings are similar to Liang *et al*. (1994), Gerami *et al*. (2012) and Pati *et al*. (2016), who also reported the beneficial role of Si fertilizer in increasing number of tillers per hill. Islam *et al*. (2017) also found similar result of the present study.

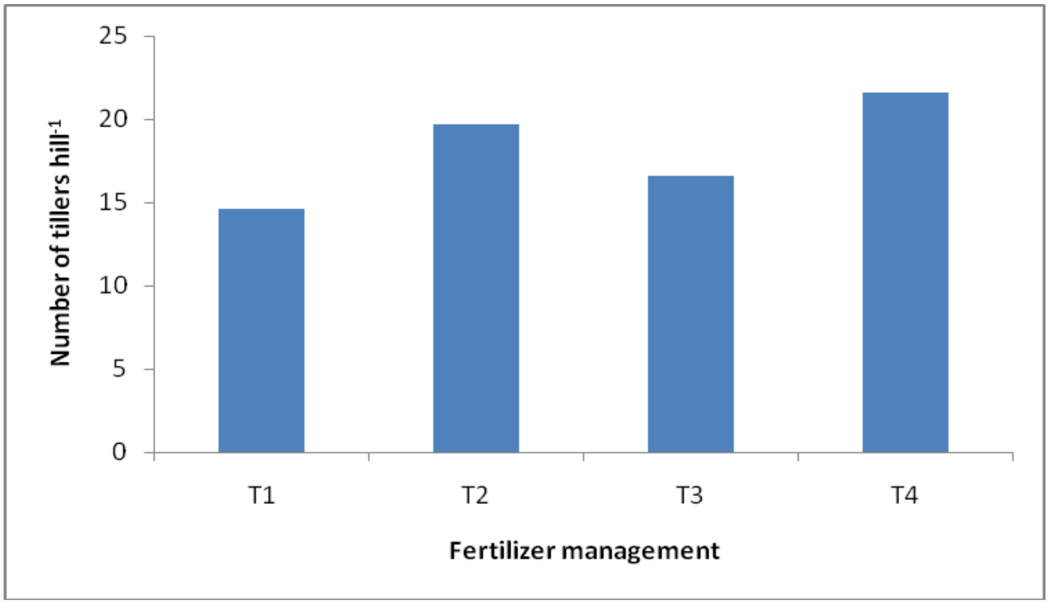

Figure 5. Number of tillers hill^{-1} as influenced by different fertilizer management

T_1 = {30(BS*) +20 (MT) + 10 (BPI)} kg ha^{-1} + no silicon and cow-dung, T_2 = {30(BS) +20 (MT) + 10 (BPI)} kg ha^{-1} + silicon (450 SiO_2 kg ha^{-1}) + no cow-dung, T_3 = {30(BS*) +20 (MT) + 10 (BPI)} kg ha^{-1} + No silicon + cow-dung (6 t ha^{-1}), T_4 = {30(BS) +20 (MT) + 10 (BPI)} kg ha^{-1} + silicon (450 SiO_2 kg ha^{-1}) + cow-dung (6 t ha^{-1})

**BS= basal dose; MT= mid-tillering and BPI= before panicle initiatio*

Combined effect of variety and fertilizer management

Variation on number of tillers hill^{-1} was noted as influenced by combined effect of variety and fertilizer management (Appendix V). It was found that the treatment combination V_1T_4 gave the highest number of tillers hill^{-1} (23.73) which was significantly different from other treatment combinations followed by V_2T_4. The lowest number of tillers hill^{-1} (13.93) was recorded from the treatment combination of V_3T_1 and it was significantly similar with V_1T_1 and V_2T_1 (Figure 6). This result indicated that the performance of variety

Badshabhog combined with the treatment {30(BS) + 20 (MT) + 10 (BPI)} kg ha^{-1} + silicon (450 SiO_2 kg ha^{-1}) was best combination for producing number of tillers $hill^{-1}$ compared to other varieties with fertilizer treatments including control. Similar result was also observed by Sarkar and Sarkar (2014).

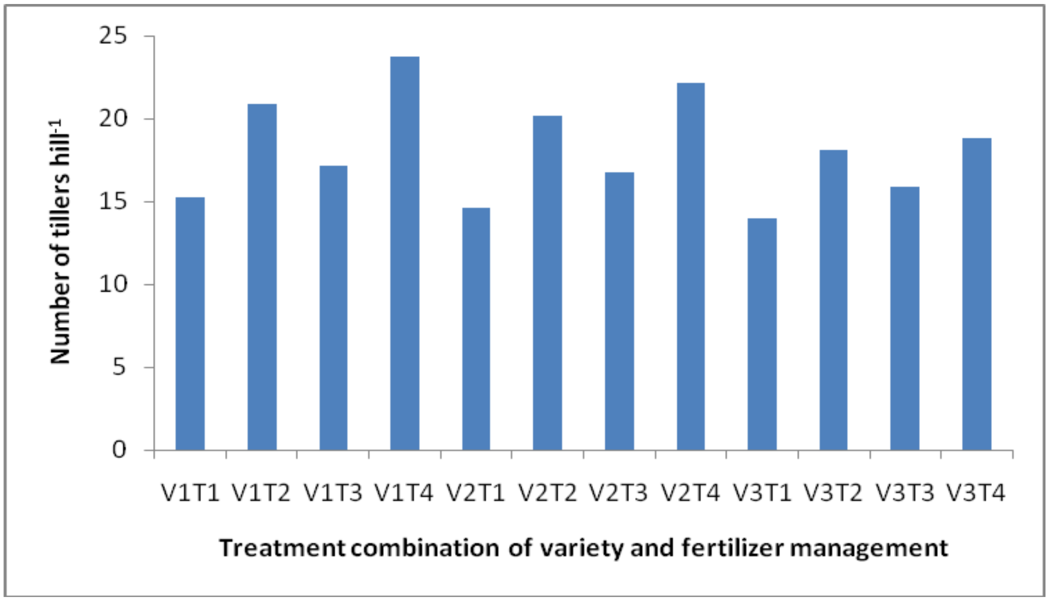

Figure 6. Number of tillers $hill^{-1}$ as influenced by combined effect of different variety and fertilizer management

V_1 = Badshabhog, V_2 = Chiniatab, V_3 = Kataribhog

T_1 = {30(BS*) +20 (MT) + 10 (BPI)} kg ha^{-1} + no silicon and cow-dung, T_2 = {30(BS) +20 (MT) + 10 (BPI)} kg ha^{-1} + silicon (450 SiO_2 kg ha^{-1}) + no cow-dung, T_3 = {30(BS*) +20 (MT) + 10 (BPI)} kg ha^{-1} + No silicon + cow-dung (6 t ha^{-1}), T_4 = {30(BS) +20 (MT) + 10 (BPI)} kg ha^{-1} + silicon (450 SiO_2 kg ha^{-1}) + cow-dung (6 t ha^{-1})

**BS= basal dose; MT= mid-tillering and BPI= before panicle initiatio*

4.1.3 Leaf area index

Effect of variety

Leaf area index was influenced significantly due to varietal difference of rice (Appendix V). Table 1 showed that the highest leaf area index (3.98) was recorded from the variety V_1 (Badshabhog) which was significantly same with V_2 (Chiniatab) whereas the variety V_3 (Kataribhog) gave the lowest leaf area index (3.36). Sritharan and Vijayalakshmi (2012) also found similar result with the present study.

Effect of fertilizer management

Variation on leaf area index was observed which was influenced by different fertilizer treatment (Appendix V). The highest leaf area index (4.57) was recorded from the treatment T_4 which was significantly different from other treatments followed by the treatment T_2 whereas the lowest leaf area index (2.80) was recorded from the control treatment T_1 (Table 1). Mactal and Canare (2016) and Zhang *et al*. (2020) also found similar result of the present study.

Combined effect of variety and fertilizer management

Treatment combination of variety and fertilizer management showed statistically significant variation on leaf area index (Appendix V). Results revealed that the highest leaf area index (4.97) was recorded from the treatment combination of V_1T_4 and this treatment combination was significantly similar with V_2T_4 followed by V_1T_2 (Table 1). The lowest leaf area index (2.68) was recorded from the treatment combination of V_3T_1 and it was statistically identical with V_2T_1. This result suggested that that for achieving highest leaf area index, variety Badshabhog combined with {30(BS) + 20 (MT) + 10 (BPI)} kg ha^{-1} + silicon (450 SiO_2 kg ha^{-1}) treatment was best compared to other treatment combinations of the study. This result was similar with the findings of Zhang *et al*. (2020).

4.1.4 Leaf area hill^{-1} (cm^2)

Effect of variety

Leaf area hill^{-1} affected significantly due to varietal difference (Appendix V). It was found from Table 1 that the highest leaf area hill^{-1} (429.40 cm^2) was recorded from the variety V_1 (Badshabhog) followed by V_2 (Chiniatab) whereas the lowest leaf area hill^{-1} (411.80 cm^2) was recorded from the variety V_3 (Kataribhog). The result obtained from the present was similar with the findings of Sritharan and Vijayalakshmi (2012).

Table 1. Response to growth parameters regarding leaf area index, leaf area hill^{-1} and diameter of 4th internode of aromatic rice varieties as influenced by different variety, fertilizer management and their combinations

Treatments	Growth parameters		
	Leaf area index	Leaf area hill^{-1} (cm^2)	Diameter of 4th (W_3) internode (mm)
Effect of variety			
V_1	3.98 a	429.40 a	4.23
V_2	3.75 a	423.60 b	4.19
V_3	3.36 b	411.80 c	4.18
$LSD_{0.05}$	0.291	3.157	NS
CV(%)	6.10	11.88	6.57
Effect of fertilizer management			
T_1	2.80 d	389.10 d	3.56 b
T_2	4.13 b	436.30 b	4.40 a
T_3	3.28 c	414.30 c	4.35 a
T_4	4.57 a	446.70 a	4.48 a
$LSD_{0.05}$	0.131	3.646	0.186
CV(%)	6.10	11.88	6.57
Combined effect of variety and fertilizer management			
V_1T_1	2.97 g	391.60 h	3.67 e
V_1T_2	4.53 b	439.40 cd	4.50 b
V_1T_3	3.43 e	413.90 f	4.15 d
V_1T_4	4.97 a	457.10 a	4.78 a
V_2T_1	2.74 h	390.80 hi	3.57 ef
V_2T_2	4.17 c	444.80 bc	4.48 bc
V_2T_3	3.27 ef	424.80 e	4.11 d
V_2T_4	4.80 a	449.70 b	4.58 ab
V_3T_1	2.68 h	384.90 i	3.43 f
V_3T_2	3.71 d	424.80 e	4.22 d
V_3T_3	3.12 fg	404.20 g	4.61 ab
V_3T_4	3.93 d	433.20 d	4.28 cd
$LSD_{0.05}$	0.227	6.315	0.214
CV(%)	6.10	11.88	6.57

In a column means having similar letters) arc statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

V_1 = Badshabhog, V_2 = Chiniatab, V_3 = Kataribhog

T_1 = {30(BS*) +20 (MT) + 10 (BPI)} kg ha^{-1} + no silicon and cow-dung, T_2 = {30(BS) +20 (MT) + 10 (BPI)} kg ha^{-1} + silicon (450 SiO_2 kg ha^{-1}) + no cow-dung, T_3 = {30(BS*) +20 (MT) + 10 (BPI)} kg ha^{-1} + No silicon + cow-dung (6 t ha^{-1}), T_4 = {30(BS) +20 (MT) + 10 (BPI)} kg ha^{-1} + silicon (450 SiO_2 kg ha^{-1}) + cow-dung (6 t ha^{-1})

**BS= basal dose; MT= mid-tillering and BPI= before panicle initiation*

Effect of fertilizer management

Leaf area hill^{-1} was found significant with the application of different fertilizer treatment (Appendix V). The treatment T_4 showed the highest leaf area hill^{-1} (446.70 cm^2) which was significantly different from other treatments followed by the treatmentT_2 whereas the lowest leaf area hill^{-1} (389.10 cm^2) was recorded from the control treatment T_1 (Table 1). Similar result was also observed by Mactal and Canare (2016) and Zhang *et al*. (2020).

Combined effect of variety and fertilizer management

Variation on leaf area hill^{-1} was significantly varied due to treatment combinations of variety and fertilizer management (Appendix V). Results from the Table 1 revealed that the highest (457.10 cm^2) was recorded from the treatment combination of V_1T_4 which was significantly different from other treatment combinations followed by V_2T_4. The treatment combination V_3T_1 showed the lowest leaf area hill^{-1} (384.90 cm^2) and it was statistically similar with V_2T_1. From the present study it was reported that the treatment combination V_1T_4 was best for obtaining highest leaf area hill^{-1} compared to other treatment combinations.

4.1.5 Diameter of 4th (W_3) internode (mm)

Effect of variety

Non-significant influence was recorded on diameter of 4th (W_3) internode as affected by different rice varieties (Appendix V). However, the highest diameter of 4th (W_3) internode (4.23 mm) was recorded from the variety V_1 (Badshabhog) whereas the lowest diameter of 4th (W_3) internode (4.18 mm) was recorded from the variety V_3 (Kataribhog). Probably, varieties under the present study bears same genetical characters of internode diameter which might be resulted non-significant difference on diameter of 4th internode among the varieties. Zhang *et al*. (2016) also found similar result with the present study.

Effect of fertilizer management

Significant variation was found for diameter of 4th (W_3) internode influenced by different fertilizer treatment (Appendix V). It is evident from Table 1 that the highest diameter of 4th (W_3) internode (4.48 mm) was recorded from the treatment T_4 and it was significantly same with the treatment T_2 and T_3 whereas the lowest diameter of 4th (W_3) internode (3.56 mm) was recorded from the control treatment T_1. Similar result was also observed by Salman *et al*. (2012) which supported the present study. Mactal and Canare (2016) and Duy *et al.* (2004) also recorded similar result with the present study.

Combined effect of variety and fertilizer management

Combined effect of variety and fertilizer management gave significant influence on diameter of 4th (W_3) internode (Appendix V). Results revealed that the treatment combination of V_1T_4 showed the highest diameter of 4th (W_3) internode (4.78 mm) and it was significantly similar with V_2T_4 and V_3T_3 (Table 1). The lowest diameter of 4th (W_3) internode (3.43 mm) was recorded from the treatment combination of V_3T_1. Significantly similar result was also observed by V_2T_1 with V_3T_1.

4.1.6 Culm height (cm)

Effect of variety

The recorded data on culm height was significantly influence by different rice varieties (Appendix VI). Table 2 showed that the variety V_1 (Badshabhog) produced highest culm height (75.97 cm) which was statistically identical with V_2 (Chiniatab) whereas variety V_3 (Kataribhog) performed lowest culm height (71.89 cm). Similar result was also observed by Shahidullaha *et al*. (2009) who found rice cultivars showed variation on culm diameter, height and thickness.

Effect of fertilizer management

Different fertilizer treatment showed significant influence on culm height (Appendix VI). The highest culm height (79.75 cm) was recorded from treatment T_4 followed by the treatment T_2 whereas the control treatment T_1 showed the lowest culm height (67.20 cm) (Table 2). This result was similar to the findings of Duy *et al*. (2004).

Combined effect of variety and fertilizer management

Considerable influence was observed on culm height persuaded by treatment combination of variety and fertilizer management (Appendix VI). Treatment combination of V_1T_4 performed the highest culm height (82.23 cm) which was statistically similar with the treatment combination of V_2T_4 followed by V_1T_2. The lowest culm height (65.77 cm) was fond from the treatment combination of V_3T_1which was statistically similar with V_2T_1 (Table 2).

4.1.7 Culm dry weight cm^{-1} from N_3 internode (mg)

Effect of variety

The data on culm dry weight cm^{-1} from N_3 internode obtained from different rice varieties was significantly varied (Appendix VI). It is evident from Table 2 that the highest culm dry weight cm^{-1} from N_3 internode (9.83 mg) was recorded from the variety V_1 (Badshabhog) followed by V_2 (Chiniatab) whereas the lowest culm dry weight cm^{-1} from N_3 internode (8.23 mg) was recorded from the variety V_3 (Kataribhog). Khatun *et al*. (2020) and Sritharan and Vijayalakshmi (2012) also observed that dry matter content varied significantly due to varietal difference which might affect culm dry weight that supported the present study.

Effect of fertilizer management

Considerable influence was observed on culm dry weight cm^{-1} from N_3 internode influenced by different fertilizer management treatments (Appendix VI). Results indicated that the treatment T_4 gave the highest culm dry weight cm^{-1} from N_3 internode (11.35 mg) which was significantly different from other treatments followed by the treatmentT_2 whereas the lowest culm dry weight cm^{-}

[1] from N_3 internode (6.63 mg) was found from the control treatment T_1 (Table 2). Agarie *et al*. (1993) and Matsuo *et al*. (1995) also reported that silicate fertilizers and/or other nutrients increased dry matters by effect on vegetation growth in rice which supported the present finding.

Combined effect of variety and fertilizer management

Treatment combination of different variety and fertilizer management showed significant variation on culm dry weight cm^{-1} from N_3 internode (Appendix VI). Results revealed that the highest culm dry weight cm^{-1} from N_3 internode (12.18 mg) was recorded from the treatment combination of V_1T_4 and statistically identical result was also obtained from V_2T_4 with V_1T_4 followed by V_1T_2 and V_2T_2 (Table 2). The lowest culm dry weight cm^{-1} from N_3 internode (6.40 mg) was recorded from the treatment combination of V_3T_1 which was statistically similar with V_2T_1.

4.1.8 Fresh weight of N_1 and N_2 internodes with leaf and leaf sheath

Effect of variety

Considerable influence was observed on fresh weight of the N_1 and N_2 internodes with leaf and leaf sheath persuaded by varietal variations (Appendix VI). The highest fresh weight of the N_1 and N_2 internodes with leaf and leaf sheath (46.45 g) was recorded from the variety V_1 (Badshabhog) which was statistically identical withV_2 (Chiniatab) whereas the lowest fresh weight of the N_1 and N_2 internodes with leaf and leaf sheath (42.18 g) was recorded from the variety V_3 (Kataribhog) (Table 2). This result might also be supported by Fan *et al*. (2017) who reported that fresh weight differed significantly due to varietal difference of giant rice varieties.

Table 2. Response to growth parameters regarding culm height, culm dry weight cm^{-1} from N_3 internodes and fresh weight of the N_1 and N_2 internodes with leaf and leaf sheath as influenced by different aromatic rice varieties, fertilizer management and their combinations

Treatment	Growth parameters		
	Culm height (cm)	Culm dry weight cm^{-1} from N_3 internode (mg)	Fresh weight of N_1 and N_2 internodes with leaf and leaf sheath (g)
Effect of variety			
V_1	75.97 a	9.83 a	46.45 a
V_2	74.72 a	9.57 b	45.26 a
V_3	71.89 b	8.23 c	42.18 b
$LSD_{0.05}$	1.475	0.136	1.308
CV(%)	11.65	7.83	11.39
Effect of fertilizer management			
T_1	67.20 d	6.63 d	37.64 d
T_2	77.69 b	10.39 b	48.19 b
T_3	72.13 c	8.47 c	42.53 c
T_4	79.75 a	11.35 a	50.15 a
$LSD_{0.05}$	1.395	0.1576	1.151
CV(%)	11.65	7.83	11.39
Combined effect of variety and fertilizer management			
V_1T_1	68.37 gh	6.85 fg	39.23 gh
V_1T_2	79.58 b	10.87 b	50.27 ab
V_1T_3	73.68 ef	9.41 d	44.27 de
V_1T_4	82.23 a	12.18 a	52.02 a
V_2T_1	67.47 hi	6.63 gh	37.93 h
V_2T_2	78.20 bc	10.74 b	48.83 b
V_2T_3	72.60 f	8.89 e	42.57 ef
V_2T_4	80.61 ab	12.03 a	51.70 a
V_3T_1	65.77 i	6.40 h	35.77 i
V_3T_2	75.30 de	9.55 d	45.47 cd
V_3T_3	70.11 g	7.11 f	40.77 fg
V_3T_4	76.40 cd	9.84 c	46.73 c
$LSD_{0.05}$	2.416	0.273	1.994
CV(%)	11.65	7.83	11.39

In a column means having similar letters) arc statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

V_1 = Badshabhog, V_2 = Chiniatab, V_3 = Kataribhog

T_1 = {30(BS*) +20 (MT) + 10 (BPI)} kg ha^{-1} + no silicon and cow-dung, T_2 = {30(BS) +20 (MT) + 10 (BPI)} kg ha^{-1} + silicon (450 SiO_2 kg ha^{-1}) + no cow-dung, T_3 = {30(BS*) +20 (MT) + 10 (BPI)} kg ha^{-1} + No silicon + cow-dung (6 t ha^{-1}), T_4 = {30(BS) +20 (MT) + 10 (BPI)} kg ha^{-1} + silicon (450 SiO_2 kg ha^{-1}) + cow-dung (6 t ha^{-1})

**BS= basal dose; MT= mid-tillering and BPI= before panicle initiation*

Effect of fertilizer management

The recorded data on fresh weight of the N_1 and N_2 internodes with leaf and leaf sheath was significantly influence by different fertilizer management (Appendix VI). The highest fresh weight of the N_1 and N_2 internodes with leaf and leaf sheath (50.15 g) was recorded from the treatment T_4which was significantly different from other fertilizer treatments followed by treatmentT_2whereas the lowest fresh weight of the N_1 and N_2 internodes with leaf and leaf sheath (37.64 g) was recorded from the control treatment T_1 (Table 2). Similar result was also observed by Fallah (2008).

Combined effect of variety and fertilizer management

Treatment combination of different variety and fertilizer management showed considerable variation on fresh weight of N_1 and N_2 internodes with leaf and leaf sheath (Appendix VI). The highest fresh weight of the N_1 and N_2 internodes with leaf and leaf sheath (52.02 g) was recorded from the treatment combination of V_1T_4 which was statistically similar with V_2T_4 and V_1T_2. The lowest fresh weight of the N_1 and N_2 internodes with leaf and leaf sheath (35.77 g) was recorded from the treatment combination of V_3T_1 which was significantly different from other treatment combinations. Duy *et al*. (2004) also recorded similar result with the present study.

4.1.9 Chlorophyll content (mg g^{-1}) in flag leaf

Effect of variety

Non-significant variation was found for Chlorophyll a and b content in flag leaf among the varieties (Appendix VII). However, the highest Chlorophyll a and Chlorophyll b (2.12 mg g^{-1} and 1.23 mg g^{-1}, respectively) content in flag leaf was found from V_1 (Badshabhog) whereas the lowest Chlorophyll a and Chlorophyll b (1.72 mg g^{-1} and 0.93 mg g^{-1}, respectively) content in flag leaf was found from the variety V_3 (Kataribhog) (Table 3). In terms of Total chlorophyll content in flag leaf varied significantly due to varietal difference (Appendix VII). The highest Total chlorophyll (22.93 mg g^{-1}) content in flag leaf was found from V_1 (Badshabhog) which was statistically identical with V_2 (Chiniatab) whereas the lowest Total chlorophyll content (2.37 mg g^{-1}) in flag leaf was found from the variety V_3 (Kataribhog) (Table 3). The results obtained from the present study was similar with the findings of Islam *et al*. (2017) who found variation in chlorophyll content due to varietal difference.

Effect of fertilizer management

Significant variation was observed for Chlorophyll a, Chlorophyll b and Total chlorophyll content in flag leaf among the varieties (Appendix VII). In terms of Chlorophyll a content in flag leaf, the highest (2.50 mg g^{-1}) was found from the treatment T_4 which was statistically identical with T_2 whereas the lowest (1.31 mg g^{-1}) was recorded from the control treatment T_1 (Table 3). Regarding, Chlorophyll b content in flag leaf, the highest (1.70 mg g^{-1}) was found from the treatment T_4 which was statistically identical with T_2 whereas the lowest (0.47 mg g^{-1}) was recorded from the control treatment T_1 which was statistically identical with T_3 (Table 3). Similarly, Total chlorophyll content in flag leaf, the highest (3.65 mg g^{-1}) was recorded from the treatment T_4 which was significantly different from other treatments followed by T_2 whereas the lowest Total chlorophyll content in flag leaf (1.62 mg g^{-1}) was recorded from the control treatment T_1 (Table 3). Ahmed *et al*. (2011) found that the increase in silicon leads to increase in chlorophyll content (SPAD). Islam *et al*. (2017) also found similar result with the present study.

Table 3. Chlorophyll content (mg g^{-1}) in flag leaf of aromatic rice varieties as influenced by different fertilizer management to improve lodging resistance, reproductive behaviour and grain quality

Treatment	Chlorophyll content in flag leaf (mg g^{-1})		
	Chlorophyll a	Chlorophyll b	Total chlorophyll
Effect of variety			
V_1	2.12	1.23	2.93 a
V_2	1.99	1.12	2.72 a
V_3	1.72	0.93	2.37 b
$LSD_{0.05}$	NS	NS	0.318
CV(%)	11.14	15.92	12.98
Effect of fertilizer management			
T_1	1.31 c	0.47 b	1.62 d
T_2	2.31 a	1.39 a	3.24 b
T_3	1.64 b	0.81 b	2.18 c
T_4	2.50 a	1.70 a	3.65 a
$LSD_{0.05}$	0.330	0.353	0.367
CV(%)	11.14	15.92	12.98
Combined effect of variety and fertilizer management			
V_1T_1	1.41 ef	0.54 de	1.76 fg
V_1T_2	2.53 ab	1.60 ab	3.61 abc
V_1T_3	1.83 d	0.97 c	2.49 d
V_1T_4	2.69 a	1.80 a	3.86 a
V_2T_1	1.33 fg	0.47 e	1.65 fg
V_2T_2	2.43 b	1.47 b	3.41 bc
V_2T_3	1.60 e	0.81 cd	2.11 e
V_2T_4	2.60 ab	1.72 ab	3.72 ab
V_3T_1	1.19 g	0.41 e	1.46 g
V_3T_2	1.97 d	1.09 c	2.69 d
V_3T_3	1.51 ef	0.65 de	1.95 ef
V_3T_4	2.21 c	1.57 ab	3.38 c
$LSD_{0.05}$	0.2004	0.293	0.343
CV(%)	11.14	15.92	12.98

In a column means having similar letters) arc statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

V_1 = Badshabhog, V_2 = Chiniatab, V_3 = Kataribhog

T_1 = {30(BS*) +20 (MT) + 10 (BPI)} kg ha^{-1} + no silicon and cow-dung, T_2 = {30(BS) +20 (MT) + 10 (BPI)} kg ha^{-1} + silicon (450 SiO_2 kg ha^{-1}) + no cow-dung, T_3 = {30(BS*) +20 (MT) + 10 (BPI)} kg ha^{-1} + No silicon + cow-dung (6 t ha^{-1}), T_4 = {30(BS) +20 (MT) + 10 (BPI)} kg ha^{-1} + silicon (450 SiO_2 kg ha^{-1}) + cow-dung (6 t ha^{-1})

**BS= basal dose; MT= mid-tillering and BPI= before panicle initiation*

Combined effect of variety and fertilizer management

Treatment combination of variety and fertilizer management showed significant difference among the treatment combinations regarding Chlorophyll a, Chlorophyll b and Total chlorophyll content in flag leaf (Appendix VII). Considering Chlorophyll a content in flag leaf, the highest (2.69) was recorded from the treatment combination of V_1T_4 which was statistically similar with V_1T_2 and V_2T_4 whereas the lowest (1.19 mg g^{-1}) was recorded from the treatment combination of V_3T_1 which was statistically similar with V_2T_1 (Table 3). In terms of Chlorophyll b content in flag leaf, the highest (1.80 mg g^{-1}) was recorded from the treatment combination of V_1T_4 which was statistically similar with V_1T_2, V_2T_4 and V_3T_4 whereas the lowest (0.41 mg g^{-1}) was recorded from the treatment combination of V_3T_1 which was statistically similar with V_2T_1, V_1T_1 and V_3T_3 (Table 3). Regarding, Total chlorophyll content in flag leaf, the highest (3.86 mg g^{-1}) was recorded from the treatment combination of V_1T_4 which was statistically similar with V_2T_4 and V_1T_2 whereas the lowest (1.46 mg g^{-1}) was recorded from the treatment combination of V_3T_1 which was statistically similar with V_1T_1 and V_2T_1 (Table 3).

4.1.10 Internodes length (cm)

Effect of variety

The number of visible internodes are found significant to vary for different cultivars except 4th indernode (Appendix VIII). The topmost internode that bears the panicle, was considered as the first internode (Internode-1). Accordingly, the upper four internodes were measured and the rest (if there were any visible) were ignored. The highest 1st internode length (28.12 cm) was from V_1 (Badshabhog) which was statistically identical with V_2 (Chiniatab) whereas the lowest 1st internode length (26.37 cm) was from V_3 (Kataribhog). Similar trend was found for 2nd, 3rd and 4th internodes length (Table 4). The highest 2nd internode length (18.18 cm) was found from V_1 (Badshabhog which was statistically identical with V_2 (Chiniatab) whereas the lowest 2nd internode length (16.32 cm) was from V_3 (Kataribhog) (Table 4). As the same trend with 1st and 2nd internodes, V_1 (Badshabhog) produced the longest 3rd internode (9.81 cm) which was significantly same with V_2 (Chiniatab) and V_3 (Kataribhog) produced the shortest 3rd internode (8.10 cm) (Table 4). In case of 4th internode, non-significant variation was found among the varieties (Appendix VIII), however, the longest 4th internode with 5.39 cm length was recorded in V_1 (Badshabhog) whereas the shortest 4th internode with 5.16 cm length was recorded in V_3 (Kataribhog) (Table 4). In this list, the third internode is the most critical portion and sensitive to lodging (Kim, 1998).

Effect of fertilizer management

Significant variation was recorded on 1st, 2nd, 3rd and 4th internodes length of rice due to different fertilizer management treatments (Appendix VIII). The highest 1st internodes length (29.38 cm) was recorded from the treatment T_4 which was significantly different from other treatments whereas the lowest 1st internodes length (25.16 cm) was recorded from the control treatment T_1 (Table 4). Similar trend was observed for 2nd, 3rd and 4th internodes length. Accordingly, the highest 2nd internodes length (19.73 cm) was recorded from the treatment T_4 followed by T_2 whereas the lowest 2nd internodes length (14.50 cm) was recorded from the control treatment T_1 (Table 4). Similarly, the highest 3rd internodes length (10.93 cm) was recorded from the treatment T_4 followed by T_2 whereas the lowest 3rd internodes length (7.48 cm) was recorded from the control treatment T_1 (Table 4). Regarding 4th internodes length, the highest (5.81 cm) was recorded from the treatment T_4 followed by T_2 whereas the lowest (4.36 cm) was recorded from the control treatment T_1 (Table 4). Similar result was also observed by Fallah (2008) who reported that silicon improved inter-node length in rice. Yoshida (1981) stated that inter-node length decreased by less than 40 kg ha^{-1} nitrogen application. 3rd and 4th inter-nodes length are important for morphological characteristics related to lodging, because the most lodging were happened in this two areas, on the other hand 3rd and 4th inter-nodes length have positive correlation with lodging index (Islam *et al*., 2007).

Table 4. Internodes length of aromatic rice varieties as influenced by different fertilizer management to improve lodging resistance, reproductive behaviour and grain quality

Treatment	Internode length (cm)			
	1st	2nd	3rd	4th
Effect of variety				
V_1	28.12 a	18.18 a	9.81 a	5.39
V_2	27.64 a	17.85 a	9.20 a	5.25
V_3	26.37 b	16.32 b	8.10 b	5.16
$LSD_{0.05}$	0.9771	0.4292	0.8896	NS
CV(%)	8.65	10.36	8.80	9.22
Effect of fertilizer management				
T_1	25.16 d	14.50 d	7.48 d	4.36 d
T_2	28.62 b	19.02 b	9.68 b	5.57 b
T_3	26.36 c	16.55 c	8.07 c	5.34 c
T_4	29.38 a	19.73 a	10.93 a	5.81 a
$LSD_{0.05}$	0.5633	0.4956	0.315	0.186
CV(%)	8.65	10.36	8.80	9.22
Combined effect of variety and fertilizer management				
V_1T_1	25.53 efg	15.15 gh	7.75 fg	4.57 f
V_1T_2	29.54 b	19.73 b	10.47 c	5.78 ab
V_1T_3	26.85 cd	17.03 de	8.24 ef	5.16 de
V_1T_4	30.57 a	20.80 a	12.80 a	6.07 a
V_2T_1	25.17 fg	14.78 h	7.54 gh	4.35 fg
V_2T_2	29.07 b	19.53 b	10.07 c	5.64 bc
V_2T_3	26.40 de	16.73 ef	8.07 efg	5.07 e
V_2T_4	29.94 ab	20.37 ab	11.13 b	5.95 ab
V_3T_1	24.78 g	13.57 i	7.15 h	4.17 g
V_3T_2	27.25 cd	17.80 cd	8.50 de	5.29 de
V_3T_3	25.82 ef	15.88 fg	7.91 fg	5.78 ab
V_3T_4	27.64 c	18.03 c	8.85 d	5.40 cd
$LSD_{0.05}$	0.9757	0.8584	0.546	0.321
CV(%)	8.65	10.36	8.80	9.22

In a column means having similar letters) arc statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

V_1 = Badshabhog, V_2 = Chiniatab, V_3 = Kataribhog

T_1 = {30(BS*) +20 (MT) + 10 (BPI)} kg ha^{-1} + no silicon and cow-dung, T_2 = {30(BS) +20 (MT) + 10 (BPI)} kg ha^{-1} + silicon (450 SiO_2 kg ha^{-1}) + no cow-dung, T_3 = {30(BS*) +20 (MT) + 10 (BPI)} kg ha^{-1} + No silicon + cow-dung (6 t ha^{-1}), T_4 = {30(BS) +20 (MT) + 10 (BPI)} kg ha^{-1} + silicon (450 SiO_2 kg ha^{-1}) + cow-dung (6 t ha^{-1})

**BS= basal dose; MT= mid-tillering and BPI= before panicle initiation*

Combined effect of variety and fertilizer management

Internodes length (1st, 2nd, 3rd and 4th) was affected significantly due to combined effect of variety and fertilizer management (Appendix VIII). The highest 1st internodes length (30.57 cm) was recorded from the treatment combination of V_1T_4 which was statistically similar with V_2T_4 followed by V_1T_2 and V_2T_2. The lowest 1st internodes length (24.78 cm) was recorded from the treatment combination of V_3T_1 which was statistically similar with V_2T_1 and V_1T_1 (Table 4). As the same trend with 1st internodes, treatment combination of V_1T_4 showed the highest 2nd internodes length (20.80 cm) which was statistically similar with V_2T_4 whereas V_3T_1 showed the lowest 2nd internodes length (13.57 cm) which was significantly different from other treatment combinations (Table 4). As the same trend with 1st and 2nd internodes, the highest 3rd internodes length (12.80 cm) was recorded from the treatment combination of V_1T_4 followed by V_2T_4 and the highest 4th internodes length (6.07 cm) was recorded from V_1T_4 which was statistically similar with V_1T_2, V_2T_4 and V_3T_3 (Table 4). On the other hand, the lowest 3rd and 4th internodes length (7.145 and 4.17 cm, respectively) was recorded from the treatment combination of V_3T_1 which was statistically similar with V_2T_1 (Table 4).

4.2 Yield contributing parameters

4.2.1 Days to 1st flowering

Effect of variety

There was a significant variation on days to 1st flowering influenced by different varieties of rice (Appendix IX). The highest days required for 1st flowering (94.50 days) was recorded from the variety V_3 (Kataribhog) whereas the lowest days to 1st flowering (92.33 days) was recorded from the variety V_1 (Badshabhog) which was statistically identical with V_2 (Chiniatab) (Table 5). Mannan *et al.* (2012) reported similar result with the present study and observed variation in flowering due to varietal difference which might be due to cause of genetical characters of varieties.

Effect of fertilizer management

Significant variation was observed on days to 1st flowering influenced by different fertilizer management treatments (Appendix IX). The highest days to 1st flowering (94.22 days) was recorded from the treatment T_4 which was significantly different from other treatments followed by T_3 whereas the lowest days to 1st flowering (92.33 days) was recorded from the control treatment T_1 (Table 5). Miyake (1993) reported that poor Si nutrition had a negative effect on flowering which indicated that Si had positive effect on early flowering which supported the present study.

Combined effect of variety and fertilizer management

Combined effect of variety and fertilizer management had significant variation on days to 1st flowering (Appendix IX). The highest days to 1st flowering (95.33 days) was recorded from the treatment combination of V_3T_4 which was statistically similar with V_3T_3 whereas the lowest days to 1st flowering (91.33 days) was recorded from the treatment combination of V_1T_1 which was statistically similar with V_1T_2, V_1T_3 and V_2T_1 (Table 5).

4.2.2 Days to maturity

Effect of variety

Significant variation was found on days to maturity influenced by different varieties of rice (Appendix IX). The highest days to maturity (138.70 days) was recorded from the variety V_3 (Kataribhog) followed by V_2 (Chiniatab) whereas the lowest days to maturity (135.70 days) was recorded from the variety V_1 (Badshabhog) (Table 5). Islam (2011) also found similar result with the present study.

Effect of fertilizer management

Significant influence was recorded on days to maturity affected by different fertilizer management treatments (Appendix IX). The highest days to maturity (139.10 days) was recorded from the treatment T_4 which was significantly different from other treatments followed by T_3 whereas the lowest days to maturity (135.00 days) was recorded from the control treatment T_1 (Table 5). Similar result was also found by the findings of Zhang *et al*. (2016).

Combined effect of variety and fertilizer management

Combined effect of variety and fertilizer management showed significant variation on days to maturity (Appendix IX). The highest days to maturity (140.30 days) was recorded from the treatment combination of V_3T_4 which was statistically identical with V_2T_4 and V_3T_3 whereas the lowest days to maturity (133.70 days) was recorded from the treatment combination of V_1T_1 which was statistically similar with V_2T_1 (Table 5).

4.2.3 Number of filled grains panicle^{-1}

Effect of variety

Number of filled grains panicle^{-1} was affected significantly due to varietal performance of rice (Appendix IX). The highest number of filled grains panicle^{-1} (134.90) was recorded from the variety V_1 (Badshabhog) followed byV_2 (Chiniatab) whereas the lowest number of filled grains panicle^{-1} (123.30) was recorded from the variety V_3 (Kataribhog) (Table 5). Similar result was also observed by Rashid *et al*. (2017) who found significant variation among different rice varieties on filled grains panicle^{-1}.

Effect of fertilizer management

Different fertilizer management treatment on number of filled grains panicle^{-1} showed significant variation (Appendix IX). The highest number of filled grains panicle^{-1} (147.80) was recorded from the treatment T_4 followed byT_2 whereas the lowest number of filled grains panicle^{-1} (109.00) was recorded from the control treatment T_1 (Table 5). Some of the grain yield-related traits, such as number of grains per panicle were significantly increased with the addition of Si fertilizer. Lavinsky *et al*. (2016) mentioned Si as a key player to enhance number of grains in rice. Jawahar *et al*. (2015) reported the effectiveness of Si fertilizer in promoting the assimilation of carbohydrates in panicles, which leads to increased number of filled grains. Cuong *et al*. (2017) and Islam *et al*. (2017) also found similar result with the present study.

Combined effect of variety and fertilizer management

The differences on number of filled grains panicle^{-1} among the treatment combination was significant (Appendix IX). The highest number of filled grains panicle^{-1} (153.70) was recorded from the treatment combination of V_1T_4 which was statistically similar with V_2T_4 and V_1T_2. The lowest number of filled grains panicle^{-1} (106.30) was recorded from the treatment combination of V_3T_1 which was statistically similar with V_2T_1 and V_1T_1 (Table 5).

4.2.4 Sterile spikelets panicle^{-1}

Effect of variety

Significant variation was found on number of sterile spikelets panicle^{-1} influenced by different varieties of rice (Appendix IX). The highest number of sterile spikelets panicle^{-1} (23.88) was recorded from the variety V_3 (Kataribhog) whereas the lowest number of sterile spikelets panicle^{-1} (21.56) was recorded from the variety V_1 (Badshabhog) which was statistically identical with V_2 (Chiniatab) (Table 5). This result was also conformity with the findings of Khatun *et al*. (2020).

Effect of fertilizer management

Significant influence was recorded on number of sterile spikelets panicle^{-1} affected by different fertilizer management treatments (Appendix IX). The highest number of sterile spikelets panicle^{-1} (26.94) was recorded from the control treatment T_1 which was significantly different from other treatments followed by T_3 whereas the lowest number of sterile spikelets panicle^{-1} (18.95) was recorded from the treatment T_4 (Table 5). The result obtained from the present study was similar with the findings of Mactal and Canare (2016).

Combined effect of variety and fertilizer management

Combined effect of variety and fertilizer management showed significant variation on sterile spikelets panicle^{-1} (Appendix IX). The highest number of sterile spikelets panicle^{-1} (27.80) was recorded from the treatment combination of V_3T_1 which was statistically similar with V_1T_1, V_2T_1 and V_3T_3 whereas the lowest number of sterile spikelets panicle^{-1} (18.06) was recorded from the treatment combination of V_1T_4 which was statistically similar with V_1T_2, V_2T_4, V_2T_2 and V_3T_4 (Table 5).

4.2.5 Total spikelets panicle^{-1}

Effect of variety

Total spikelets panicle^{-1} was affected significantly due to varietal performance of rice (Appendix IX). The highest total spikelets panicle^{-1} (156.40) was recorded from the variety V_1 (Badshabhog) followed by V_2 (Chiniatab) whereas the lowest total spikelets panicle^{-1} (147.20) was recorded from the variety V_3 (Kataribhog) (Table 5). Similar result was also observed by Rashid *et al*. (2017) and Khan *et al*. (2006).

Effect of fertilizer management

Different fertilizer management treatment on total spikelets panicle^{-1} showed significant variation (Appendix IX). The highest total spikelets panicle^{-1} (166.80) was recorded from the treatment T_4 followed by T_2 whereas the lowest total spikelets panicle^{-1} (135.90) was recorded from the control treatment T_1 (Table 5). Cuong *et al*. (2017) and Islam *et al*. (2017) also found similar result with the present study.

Table 5. Response to yield contributing parameters of aromatic rice varieties as influenced by different fertilizer management to improve lodging resistance, reproductive behaviour and grain quality

Treatment	Yield contributing parameters				
	Days to 1st flowering	Days to maturity	No. of filled grains panicle^{-1}	Sterile spikelets panicle^{-1}	Total spikelets panicle^{-1}
Effect of variety					
V_1	92.33 b	135.70 c	134.90 a	21.56 b	156.40 a
V_2	92.83 b	136.70 b	130.70 b	22.40 b	153.10 b
V_3	94.50 a	138.70 a	123.30 c	23.88 a	147.20 c
$LSD_{0.05}$	0.5087	0.6123	2.960	1.240	2.928
CV(%)	5.64	6.53	7.15	11.69	13.92
Effect of fertilizer management					
T_1	92.33 d	135.00 d	109.00 d	26.94 a	135.90 d
T_2	92.89 c	136.00 c	141.60 b	20.00 c	161.60 b
T_3	93.44 b	137.90 b	120.10 c	24.56 b	144.70 c
T_4	94.22 a	139.10 a	147.80 a	18.95 c	166.80 a
$LSD_{0.05}$	0.4995	0.7070	3.418	1.432	3.381
CV(%)	5.64	6.53	7.15	11.69	13.92
Combined effect of variety and fertilizer management					
V_1T_1	91.33 f	133.70 f	112.10 gh	26.33 ab	138.40 fg
V_1T_2	92.00 ef	135.00 e	147.90 ab	18.77 f	166.70 ab
V_1T_3	92.33 ef	136.30 cd	125.70 e	23.10 cd	148.80 de
V_1T_4	93.67 cd	137.70 b	153.70 a	18.06 f	171.80 a
V_2T_1	92.00 ef	134.30 ef	108.60 h	26.70 ab	135.30 g
V_2T_2	92.67 de	135.30 de	144.40 bc	19.73 ef	164.20 bc
V_2T_3	93.00 cde	137.70 b	119.20 f	24.87 bc	144.00 ef
V_2T_4	93.67 cd	139.30 a	150.50 a	18.30 f	168.80 ab
V_3T_1	93.67 cd	137.00 bc	106.30 h	27.80 a	134.10 g
V_3T_2	94.00 bc	137.70 b	132.30 d	21.50 de	153.80 d
V_3T_3	95.00 ab	139.70 a	115.50 fg	25.70 ab	141.20 f
V_3T_4	95.33 a	140.30 a	139.20 c	20.50 ef	159.70 c
$LSD_{0.05}$	1.017	1.225	5.920	2.481	5.857
CV(%)	5.64	6.53	7.15	11.69	13.92

In a column means having similar letters) arc statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

V_1 = Badshabhog, V_2 = Chiniatab, V_3 = Kataribhog

T_1 = {30(BS*) +20 (MT) + 10 (BPI)} kg ha^{-1} + no silicon and cow-dung, T_2 = {30(BS) +20 (MT) + 10 (BPI)} kg ha^{-1} + silicon (450 SiO_2 kg ha^{-1}) + no cow-dung, T_3 = {30(BS*) +20 (MT) + 10 (BPI)} kg ha^{-1} + No silicon + cow-dung (6 t ha^{-1}), T_4 = {30(BS) +20 (MT) + 10 (BPI)} kg ha^{-1} + silicon (450 SiO_2 kg ha^{-1}) + cow-dung (6 t ha^{-1})

**BS= basal dose; MT= mid-tillering and BPI= before panicle initiation*

Combined effect of variety and fertilizer management

The differences on total spikelets panicle^{-1} among the treatment combination was significant (Appendix IX). The highest total spikelets panicle^{-1} (171.80) was recorded from the treatment combination of V_1T_4 which was statistically similar with V_1T_2 and V_2T_4. The lowest total spikelets panicle^{-1} (134.10) was recorded from the treatment combination of V_3T_1 which was statistically similar with V_2T_1 and V_1T_1 (Table 5).

4.2.6 Spikelets sterility (%)

Effect of variety

Significant variation was found on spikelets sterility influenced by different varieties of rice (Appendix IX). The highest spikelets sterility (16.44%) was recorded from the variety V_3 (Kataribhog) whereas the lowest spikelets sterility (14.08%) was recorded from the variety V_1 (Badshabhog) which was statistically identical with V_2 (Chiniatab) (Figure 7). This result was also conformity with the findings of Khatun *et al*. (2020) and Panwar *et al.* (2012).

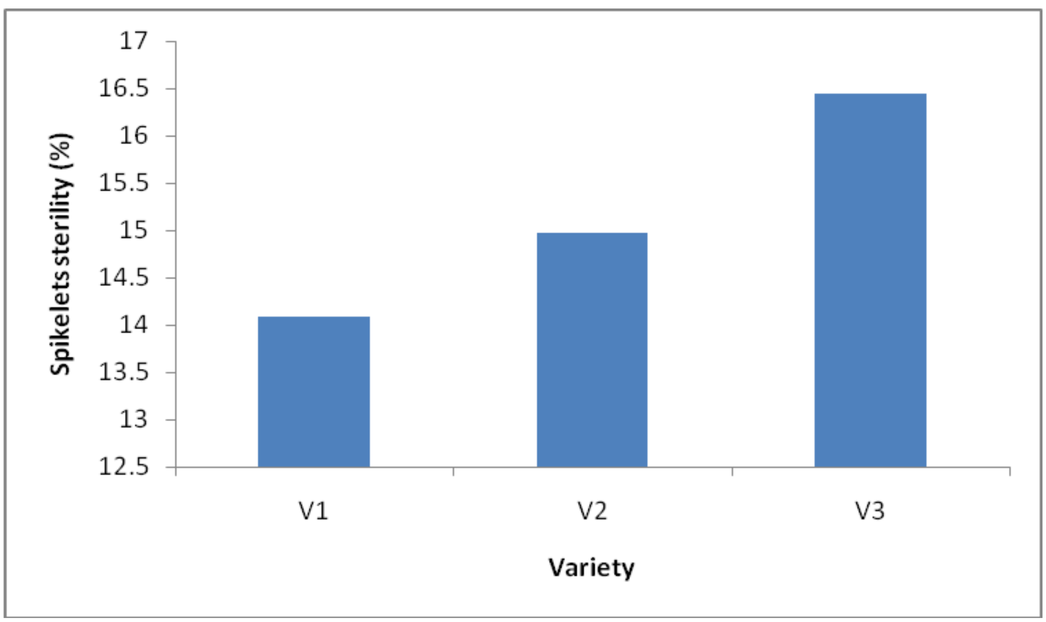

Figure 7. Spikelets sterility (%) as influenced by different varieties of rice

V_1 = Badshabhog, V_2 = Chiniatab, V_3 = Kataribhog

Effect of fertilizer management

Significant influence was recorded on spikelets sterility $^{-1}$ affected by different fertilizer management treatments (Appendix IX). The highest spikelets sterility (19.83%) was recorded from the control treatment T_1 followed by T_3 whereas the lowest spikelets sterility (11.40%) was recorded from the treatment T_4 (Figure 8). Similar result was also observed by Rashid *et al*. (2017) and Khan *et al*. (2006).

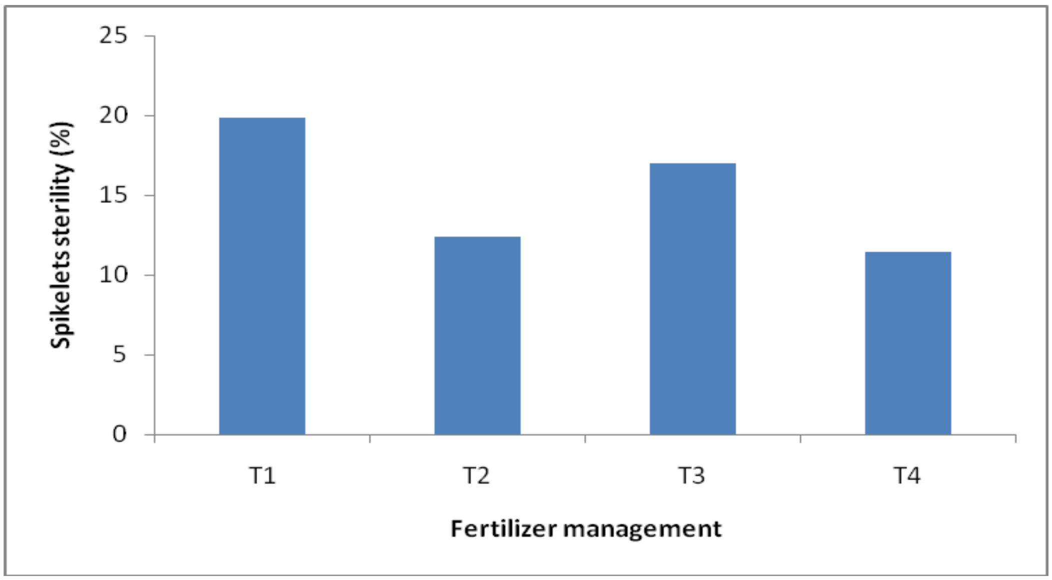

Figure 8. Spikelets sterility (%) as influenced by different fertilizer management

T_1 = {30(BS*) +20 (MT) + 10 (BPI)} kg ha^{-1} + no silicon and cow-dung, T_2 = {30(BS) +20 (MT) + 10 (BPI)} kg ha^{-1} + silicon (450 SiO_2 kg ha^{-1}) + no cow-dung, T_3 = {30(BS*) +20 (MT) + 10 (BPI)} kg ha^{-1} + No silicon + cow-dung (6 t ha^{-1}), T_4 = {30(BS) +20 (MT) + 10 (BPI)} kg ha^{-1} + silicon (450 SiO_2 kg ha^{-1}) + cow-dung (6 t ha^{-1})

**BS= basal dose; MT= mid-tillering and BPI= before panicle initiation*

Combined effect of variety and fertilizer management

Combined effect of variety and fertilizer management showed significant variation on spikelets sterility ^{1} (Appendix IX). The highest spikelets sterility (20.74%) was recorded from the treatment combination of V_3T_1 which was statistically similar with V_2T_1 whereas the lowest number of spikelets sterility (10.51%) was recorded from the treatment combination of V_1T_4 which was statistically similar with V_1T_2, V_2T_4 and V_2T_2 (Figure 9).

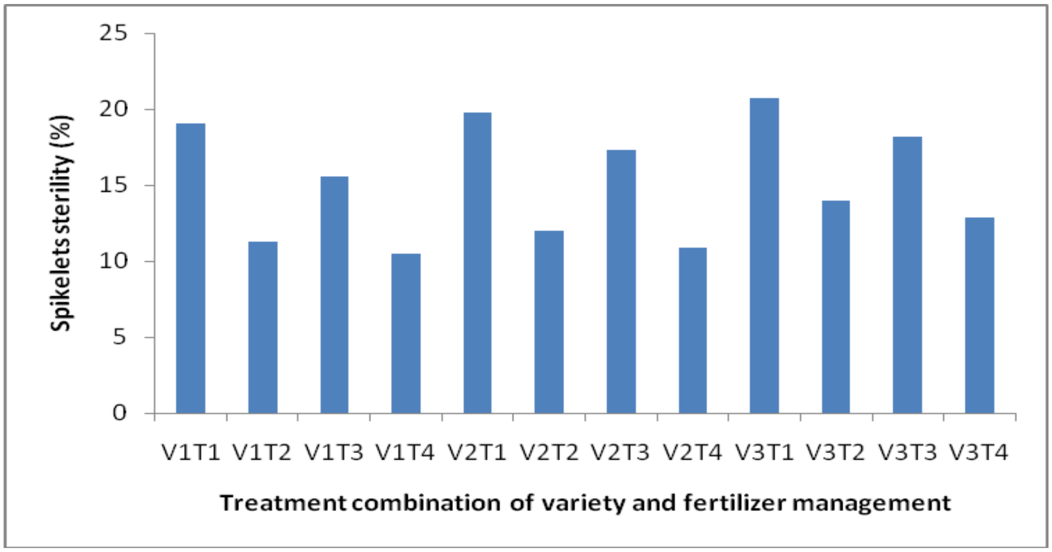

Figure 9. Spikelets sterility (%) as influenced by combined effect of different variety and fertilizer management

V_1 = Badshabhog, V_2 = Chiniatab, V_3 = Kataribhog

T_1 = {30(BS*) +20 (MT) + 10 (BPI)} kg ha^{-1} + no silicon and cow-dung, T_2 = {30(BS) +20 (MT) + 10 (BPI)} kg ha^{-1} + silicon (450 SiO_2 kg ha^{-1}) + no cow-dung, T_3 = {30(BS*) +20 (MT) + 10 (BPI)} kg ha^{-1} + No silicon + cow-dung (6 t ha^{-1}), T_4 = {30(BS) +20 (MT) + 10 (BPI)} kg ha^{-1} + silicon (450 SiO_2 kg ha^{-1}) + cow-dung (6 t ha^{-1})

**BS= basal dose; MT= mid-tillering and BPI= before panicle initiation*

4.3 Yield parameters

4.3.1 Grain weight $hill^{-1}$ (g)

Effect of variety

Different grain weight $hill^{-1}$ obtained from different variety of rice was varied significantly (Appendix X). The highest grain weight $hill^{-1}$ (7.43 g) was recorded from the V_1 (Badshabhog) which was statistically identical with V_2 (Chiniatab) whereas the lowest grain weight $hill^{-1}$ (6.69 g) was recorded from the variety V_3 (Kataribhog) (Table 6). Similar result was also observed by the findings of Mannan *et al.* (2012).

Effect of fertilizer management

Different treatments of fertilizer management showed significant variation on grain weight $hill^{-1}$ (Appendix X). The highest grain weight $hill^{-1}$ (8.13 g) was recorded from the treatment T_4 which was significantly different from other treatments followed by T_2 whereas the lowest grain weight hill^{-1} (5.76 g) was recorded from the control treatment T_1 (Table 6). Similar result was also observed by the findings of Mactal and Canare (2016).

Combined effect of variety and fertilizer management

Grain weight hill^{-1} was influenced significantly due to treatment combination of different variety and fertilizer management (Appendix X). The highest grain weight hill^{-1} (8.51 g) was recorded from the treatment combination of V_1T_4 which was statistically similar with V_2T_4 and V_1T_2. The lowest grain weight hill^{-1} (5.47 g) was recorded from the V_3T_1 which was statistically similar with V_2T_1.

4.3.2 Grain yield (t ha^{-1})

Effect of variety

Different rice variety showed significant variation on grain yield (Appendix X). the variety V_1 (Badshabhog) showed the highest grain yield (2.52 t ha^{-1}) which also showed statistically same result with V_2 (Chiniatab) whereas the lowest grain yield (2.27 t ha^{-1}) was recorded from the variety V_3 (Kataribhog) (Table 6). Rashid *et al*. (2017), Sarkar *et al*. (2014) and Chowdhury *et al*. (2016) also found significant variation among different rice varieties on grain yield which supported the present study.

Effect of fertilizer management

Grain yield of rice was varied significantly due to different treatments of fertilizer management (Appendix X). The highest grain yield (2.76 t ha^{-1}) was recorded from the treatment T_4 followed by T_2 whereas the lowest grain yield (1.96 t ha^{-1}) was recorded from the control treatment T_1 (Table 6). Similar result was also observed by Prakash *et al*. (2011). Pati *et al*. (2016) also reported a significant increase in grain yields of rice with increasing Si level.

The result obtained from the present study was also similar with the findings of Islam *et al*. (2017) and Cuong *et al*. (2017).

Combined effect of variety and fertilizer management

Significant variation was remarked on grain yield as influenced by treatment combination of variety and fertilizer management (Appendix X). The highest grain yield (2.89 t ha^{-1}) was recorded from the treatment combination of V_1T_4 which was statistically similar with V_2T_4 and V_1T_2. The lowest grain yield (1.86 t ha^{-1}) was recorded from the treatment combination of V_3T_1 which was statistically similar with V_2T_1. This result obtained from the present study on grain yield was conformity with the findings of Islam *et al*. (2017) who found that interactions of Binadhan-13 and silicon rates at 600 Kg ha^{-1} showed the highest grain yield. Islam *et al*. (2017) and Sarkar and Sarkar (2014) also found similar result with the present study.

4.3.3 Straw yield (t ha^{-1})

Effect of variety

Straw yield was affected significantly due to varietal variation (Appendix X). The highest straw yield (4.67 t ha^{-1}) was recorded from the variety V_1 (Badshabhog) which was statistically identical with V_2 (Chiniatab) whereas the lowest straw yield (4.37 t ha^{-1}) was recorded from the variety V_3 (Kataribhog) (Table 6). Panwar *et al.* (2012) also found similar result with the present study who observed significant variation on straw yield among different genotypes of rice.

Effect of fertilizer management

Different fertilizer treatment showed significant variation on straw yield (Appendix X). The highest straw yield (4.98 t ha^{-1}) was recorded from the treatment T_4 followed by T_2 whereas the lowest straw yield (3.95 t ha^{-1}) was recorded from the control treatment T_1 (Table 6). Pati *et al*. (2016) reported a significant increase in straw yields of rice with increasing Si level. Similar result was also observed by Prakash *et al*. (2011). Cuong *et al*. (2017) also found similar result with the present study.

Combined effect of variety and fertilizer management

Treatment combination of variety and fertilizer management showed significant influence on straw yield (Appendix X). The treatment combination of V_1T_4 showed the highest straw yield (5.12 t ha^{-1}) which was statistically similar with V_2T_4 and V_1T_2. The treatment combination of V_3T_1 showed the lowest straw yield (3.86 t ha^{-1}) which was statistically similar with V_2T_1.

4.3.4 Biological yield

Effect of variety

Biological yield of rice was significantly influenced by different varieties (Appendix X). The highest biological yield (7.19 t ha^{-1}) recorded from the variety V_1 (Badshabhog) which was statistically identical with V_2 (Chiniatab) whereas the variety V_3 (Kataribhog) gave the lowest biological yield (6.64 t ha^{-1}) (Table 6). Roy *et al.* (2014) also found similar result with the present study.

Effect of fertilizer management

Biological yield of rice was significantly influenced by different fertilizer treatment (Appendix X). The highest biological yield (7.74 t ha^{-1}) was recorded from the treatment T_4 which was significantly different from other treatments followed by T_2 whereas the lowest biological yield (5.91 t ha^{-1}) was recorded from the control treatment T_1 (Table 6). Similar result was also observed by Prakash *et al*. (2011) and Pati *et al*. (2016) which supported the present study.

Combined effect of variety and fertilizer management

Treatment combination of variety and fertilizer management showed significant influence on biological yield (Appendix X). Table 6 showed that the treatment combination V_1T_4 gave the highest biological yield (8.02 t ha^{-1})

which was statistically similar with V_2T_4. The treatment combination V_3T_1 gave the lowest biological yield (5.72 t ha^{-1}) which was statistically identical with V_2T_1.

4.3.5 Harvest index (%)

Effect of variety

Harvest index was not affected considerably due to varietal performance (Appendix X). However, the highest harvest index (35.01%) was performed from the variety V_1 (Badshabhog) whereas the lowest harvest index (34.14%) was recorded from the variety V_3 (Kataribhog) (Table 6). The result obtained from the present study was similar with the findings of Roy *et al.* (2014) and Sritharan and Vijayalakshmi (2012).

Effect of fertilizer management

Significant variation was remarked on harvest index as influenced by different treatments of fertilizer treatment (Appendix X). The treatment T_4 performed the highest harvest index (35.68%) which was statistically identical with T_2 whereas the lowest harvest index (33.12%) was achieved from the control treatment T_1 (Table 6). Significantly positive relation between harvest index and Si fertilizer as well as other nutrients was observed by Prakash *et al*. (2011) and Pati *et al*. (2016) which supported the present study.

Combined effect of variety and fertilizer management

Harvest index was varied significantly due to treatment combination of variety and fertilizer management (Appendix X). The highest harvest index (36.09%) was obtained from the treatment combination of V_1T_4 which was statistically identical with V_1T_2 and V_2T_4. The lowest harvest index (32.51%) was found from the treatment combination of V_3T_1 which was significantly different from other treatment combinations (Table 6).

Table 6. Response to yield parameters of aromatic rice varieties as influenced by different fertilizer management to improve lodging resistance, reproductive behaviour and grain quality

Treatment	Yield parameters						
	Grain weight hill^{-1} (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest Index (%)	Ratio of spikelet no. to LA (cm^{-2})	Ratio of yield sink to LA (mg cm^{-2})
Effect of variety							
V_1	7.43 a	2.52 a	4.67 a	7.19 a	35.01	4.55 a	17.46
V_2	7.19 a	2.44 a	4.56 a	7.00 a	34.73	4.10 a	16.62
V_3	6.69 b	2.27 b	4.37 b	6.64 b	34.14	3.60 b	16.18
$LSD_{0.05}$	0.442	0.089	0.114	0.273	NS	0.493	NS
CV(%)	8.61	6.60	9.99	8.91	10.19	4.87	9.72
Effect of fertilizer management							
T_1	5.76 d	1.96 d	3.95 d	5.91 d	33.12 c	2.58 b	14.80 d
T_2	7.72 b	2.62 b	4.83 b	7.45 b	35.19 a	5.06 a	17.66 b
T_3	6.78 c	2.30 c	4.37 c	6.68 c	34.51 b	3.14 b	16.36 c
T_4	8.13 a	2.76 a	4.98 a	7.74 a	35.68 a	5.55 a	18.19 a
$LSD_{0.05}$	0.264	0.103	0.107	0.116	0.5089	0.569	0.2817
CV(%)	8.61	6.60	9.99	8.91	10.19	4.87	9.72
Combined effect of variety and fertilizer management							
V_1T_1	6.05 gh	2.06 gh	4.05 gh	6.11 h	33.66 e	2.75 gh	15.45 e
V_1T_2	8.06 ab	2.74 ab	4.94 abc	7.68 bc	35.66 a	5.68 b	18.35 b
V_1T_3	7.08 e	2.41 de	4.54 ef	6.95 e	34.64 cd	3.60 f	17.11 c
V_1T_4	8.51 a	2.89 a	5.12 a	8.02 a	36.09 a	6.17 a	18.92 a
V_2T_1	5.77 hi	1.96 hi	3.94 hi	5.90 i	33.20 f	2.54 h	14.76 f
V_2T_2	7.76 bc	2.64 bc	4.87 bc	7.51 cd	35.15 b	5.15 c	17.45 c
V_2T_3	6.85 ef	2.33 ef	4.41 f	6.74f	34.59 cd	2.94 g	16.13 d
V_2T_4	8.29 a	2.82 a	5.02 ab	7.84 ab	35.97 a	5.77 b	18.15 b
V_3T_1	5.47 i	1.86 i	3.86 i	5.72 i	32.51 g	2.45 h	14.21 g
V_3T_2	7.30 de	2.48 cde	4.66 de	7.15 e	34.75 bcd	4.34 e	17.19 c
V_3T_3	6.40 fg	2.18 fg	4.17 g	6.34 g	34.31 d	2.88 g	15.84 de
V_3T_4	7.58 cd	2.58 bcd	4.79 cd	7.37 d	34.98 bc	4.71 d	17.49 c
$LSD_{0.05}$	0.458	0.178	0.186	0.200	0.4512	0.334	0.4878
CV(%)	8.61	6.60	9.99	8.91	10.19	4.87	9.72

In a column means having similar letters) arc statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

V_1 = Badshabhog, V_2 = Chiniatab, V_3 = Kataribhog

T_1 = {30(BS*) +20 (MT) + 10 (BPI)} kg ha^{-1} + no silicon and cow-dung, T_2 = {30(BS) +20 (MT) + 10 (BPI)} kg ha^{-1} + silicon (450 SiO_2 kg ha^{-1}) + no cow-dung, T_3 = {30(BS*) +20 (MT) + 10 (BPI)} kg ha^{-1} + No silicon + cow-dung (6 t ha^{-1}), T_4 = {30(BS) +20 (MT) + 10 (BPI)} kg ha^{-1} + silicon (450 SiO_2 kg ha^{-1}) + cow-dung (6 t ha^{-1})

**BS= basal dose; MT= mid-tillering and BPI= before panicle initiation*

4.3.6 Ratio of spikelet no. to LA (cm^{-2})

Effect of variety

Significant variation was obtained on ratio of spikelet no. to LA as affected by different rice variety (Appendix X). The highest ratio of spikelet no. to LA (4.55 cm^2) was recorded from the variety V_1 (Badshabhog) which was statistically identical with V_2 (Chiniatab) whereas the lowest ratio of spikelet no. to LA (3.60 cm^2) was recorded from the variety V_3 (Kataribhog). Panwar *et al.* (2012) found variation of leaf area due to varietal difference. Again, Khatun *et al*. (2020) also revealed the significant variation of spikelet no. due to varietal difference. So, ratio of spikelet no. to LA might be varied due to varietal difference that supported the present study.

Effect of fertilizer management

Different fertilizer treatment showed statistically significant variation on ratio of spikelet no. to LA (Appendix X). The highest ratio of spikelet no. to LA (5.55 cm^2) was recorded from the treatment T_4 which was statistically identical with T_2 whereas the lowest ratio of spikelet no. to LA (2.58 cm^2) was recorded from the control treatment T_1 which was statistically identical with T_3 (Table 6). Mactal and Canare (2016) observed significant variation on spikelet no. and LA in rice due to different levels of nutrient management which might be resulted varied ratio of spikelet no. to LA among the treatments which supported the present study.

Combined effect of variety and fertilizer management

The treatment combinations of variety and fertilizer management exhibited significant variation on ratio of spikelet no. to LA (Appendix X). Treatment combination of V_1T_4 performed the highest ratio of spikelet no. to LA (6.17 cm^2) followed by V_1T_2 and V_2T_4 whereas V_3T_1 showed the lowest ratio of spikelet no. to LA (2.45 cm^2) which was statistically similar with V_2T_1 and V_1T_1 (Table 6).

4.3.7 Ratio of yield sink to LA (mg cm^{-2})

Effect of variety

Non-significant variation was recorded on ratio of yield sink to LA due to varietal difference of rice (Appendix X). However, the highest ratio of yield sink to LA (17.46 cm^2) was recorded from the variety V_1 (Badshabhog) whereas the lowest ratio of yield sink to LA (16.18 cm^2) was recorded from the variety V_3 (Kataribhog) (Table 6). This result indicated that variety had no significant influence on ratio of yield sink to LA.

Effect of fertilizer management

Different fertilizer treatment showed significant variation on ratio of yield sink to LA (Appendix X). The highest ratio of yield sink to LA (18.19 cm^2) was recorded from the treatment T_4 which was significantly different from other treatments followed by T_2 whereas the lowest ratio of yield sink to LA (14.80 cm^2) was recorded from the control treatment T_1 (Table 6). This result suggested that that ratio of yield sink to LA might be increased or decreased by different levels nutrients management because it significantly affected yield sink to LA among the treatments.

Combined effect of variety and fertilizer management

Different treatment combination of variety and fertilizer management exhibited significant variation on ratio of yield sink to LA (Appendix X). The highest ratio of yield sink to LA (18.92 cm^2) was recorded from the treatment combination of V_1T_4 which was significantly different from other treatment combinations followed by V_1T_2 and V_2T_4. The lowest ratio of yield sink to LA (14.21 cm^2) was recorded from the treatment combination of V_3T_1 which was significantly different from other treatment combinations (Table 6).

4.4 Lodging severity at maturity

Effect of variety

Significant variation was observed on lodging severity at maturity depending on lodging score (0-9) influenced by different rice varieties (Appendix XI). Here, it can be stated that '0' indicates no lodging, '1' indicates less than 20% of plants lodged, '3' indicates 20-40% of plants lodged, '5' indicates 41-60% of plants lodged, '7' indicates 61-80% of plants lodged and '9' indicates more than 80% of plants lodged. Depending on lodging score, the highest lodging severity was found in V_3 (Kataribhog) and lodging score was 5.00 which indicates 41-60% of plants lodged whereas the lowest lodging severity was found in V_2 (Chiniatab) and lodging score was 3.00 which indicates less than 20% of plants lodged regarding the variety V_1 (Badshabhog) (Lodging score = 3.25) (Table 7). Shahidullaha *et al*. (2009) also found similar result with the present study.

Effect of fertilizer management

Significant variation was found on lodging severity at maturity depending on lodging score (0-9) influenced by different treatments of fertilizer management (Appendix XI). The highest lodging severity was found in the treatment T_1 (Lodging score = 7.67) followed by the treatment T_3 (Lodging score = 5.67) whereas the lowest lodging severity was obtained from the treatment T_4 (Lodging score = 0.33) (Table 7). This result is agreed with Ma and Yamaji (2006) who reported that silicon contents in rice stem had a direct relation with lodging resistance.

Combined effect of variety and fertilizer management

Lodging severity varied significantly among the treatment combinations of variety and fertilizer management (Appendix XI). Treatment combination V_3T_1 showed the highest lodging severity (Lodging score = 9.00) followed by V_1T_1, V_2T_1 and V_3T_3 (Lodging score = 7.00). No lodging was found in V_1T_4, V_2T_2

and V_2T_4 (Lodging score = 0) where V_1T_2 and V_3T_4 showed lower lodging severity (Lodging score = 1.00) (Table 7).

4.5 Aroma test

Effect of variety

Significant variation was found for aroma test among the varieties of rice depending on (0-3) (Appendix XI). Here, it can be noted that '0' indicates absence of aroma, '1' indicates slight aroma, '2' indicates moderate aroma and '3' indicates strong aroma. From this point of view, the variety V_2 (Chiniatab) showed strong aroma (Aroma score = 3) whereas V_1 (Badshabhog) showed moderate aroma (Aroma score = 2) and V_3 (Kataribhog) showed slight aroma (Aroma score = 1) (Table 7). The variation of aroma in different rice varieties might be due to cause of genetical characters of different rice varieties on aroma.

Effect of fertilizer management

Different fertilizer management treatment had no significant effect on aroma quality (Appendix XI). Results indicated that all the treatments showed moderate aroma quality (Aroma score = 2). This results indicated that nutrient management had no effect on aroma quality of rice.

Combined effect of variety and fertilizer management

Aroma quality varied significantly among the treatment combinations of variety and fertilizer management (Appendix XI). The treatment combinations; V_2T_1, V_2T_2, V_2T_3 and V_2T_4 showed strong aroma (Aroma score = 3) whereas V_3T_1, V_3T_2, V_3T_3 and V_3T_4 showed slight aroma (Aroma score = 1) and rest of the treatment combinations V_2T_1, V_2T_2, V_2T_3 and V_2T_4 showed moderate aroma (Aroma score = 2) (Table 7).

Table 7. Response to lodging severity and aroma test as influenced by different aromatic rice varieties and fertilizer management

Treatment	Lodging severity at maturity	Aroma Test
	Lodging score (0-9)	Aroma score (0-3)
Effect of variety		
V_1	3.25 b	2.00 b
V_2	3.00 b	3.00 a
V_3	5.00 a	1.00 c
$LSD_{0.05}$	0.422	0.137
CV(%)	8.41	6.52
Effect of fertilizer management		
T_1	7.67 a	2.00
T_2	1.33 c	2.00
T_3	5.67 b	2.00
T_4	0.33 d	2.00
$LSD_{0.05}$	0.344	NS
CV(%)	8.41	6.52
Combined effect of variety and fertilizer management		
V_1T_1	7.00 b	2.00 b
V_1T_2	1.00 e	2.00 b
V_1T_3	5.00 c	2.00 b
V_1T_4	0.00 f	2.00 b
V_2T_1	7.00 b	3.00 a
V_2T_2	0.00 f	3.00 a
V_2T_3	5.00 c	3.00 a
V_2T_4	0.00 f	3.00 a
V_3T_1	9.00 a	1.00 c
V_3T_2	3.00 d	1.00 c
V_3T_3	7.00 b	1.00 c
V_3T_4	1.00 e	1.00 c
$LSD_{0.05}$	0.524	0.204
CV(%)	8.41	6.52

In a column means having similar letters) arc statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

V_1 = Badshabhog, V_2 = Chiniatab, V_3 = Kataribhog

T_1 = {30(BS*) +20 (MT) + 10 (BPI)} kg ha^{-1} + no silicon and cow-dung, T_2 = {30(BS) +20 (MT) + 10 (BPI)} kg ha^{-1} + silicon (450 SiO_2 kg ha^{-1}) + no cow-dung, T_3 = {30(BS*) +20 (MT) + 10 (BPI)} kg ha^{-1} + No silicon + cow-dung (6 t ha^{-1}), T_4 = {30(BS) +20 (MT) + 10 (BPI)} kg ha^{-1} + silicon (450 SiO_2 kg ha^{-1}) + cow-dung (6 t ha^{-1})

**BS= basal dose; MT= mid-tillering and BPI= before panicle initiation*

CHAPTER V

SUMMARY AND CONCLUSION

An experiment was conducted at Experimental Field of Department of Agricultural Botany, Sher-e-Bangla Agricultural University (SAU) to study the improvement of lodging resistance, reproductive behaviour and grain quality of traditional aromatic rice cultivars through nitrogen, silicon and organic fertilizer management in *Boro* season, 2019-20. The experiment comprised of two different factors such as (1) three aromatic rice varieties *viz*. V_1 = Badshabhog, V_2 = Chiniatab (awnless) and V_3 = Kataribhog (awnless) and (2) four levels of fertilizer management *viz*. T_1 = {30(BS) +20 (MT) + 10 (BPI)} kg ha^{-1} + no silicon and cow-dung, T_2 = {30(BS) +20 (MT) + 10 (BPI)} kg ha^{-1} + silicon (450 SiO_2 kg ha^{-1}) + no cow-dung, T_3 = {30(BS*) +20 (MT) + 10 (BPI)} kg ha^{-1} + No silicon + cow-dung (6 t ha^{-1}) and T_4 = {30(BS) +20 (MT) + 10 (BPI)} kg ha^{-1} + silicon (450 SiO_2 kg ha^{-1}) + cow-dung (6 t ha^{-1}) where BS= basal dose; MT= mid-tillering and BPI= before panicle initiation. The experiment was set up in two factor Randomized Complete Block Design (RCBD) with three replications. There were 12 treatment combinations. Data on different growth, yield contributing parameters, yield, lodging and quality parameter were recorded and analyzed statistically.

Results revealed that the variety V_1 (Badshabhog) showed the highest plant height (103.90 cm), number of tillers $hill^{-1}$ (19.25), leaf area index (3.98), leaf area $hill^{-1}$ (429.40 cm^2), diameter of 4^{th} (W_3) internode (4.23 mm), culm height (75.97 cm), culm dry weight cm^{-1} from N_3 internode (9.83 mg) and fresh weight of the N_1 and N_2 internodes with leaf and leaf sheath (46.45 g). The lowest plant height (94.47 cm) was recorded from V_2 (Chiniatab) but V_3 (Kataribhog) showed the lowest number of tillers $hill^{-1}$ (16.67), leaf area index (3.36), leaf area $hill^{-1}$ (411.80 cm^2), diameter of 4^{th} (W_3) internode (4.18 mm), culm height (71.89 cm), culm dry weight cm^{-1} from N_3 internode (8.23 mg) and fresh weight of the N_1 and N_2 internodes with leaf and leaf sheath (42.18 g).

Regarding the management of fertilizer treatments, T_4 showed best performance on growth parameters and T_1 gave least results. The highest plant height (104.40 cm), number of tillers hill^{-1} (21.56), leaf area index (4.57), leaf area hill^{-1} (446.70 cm^2), diameter of 4th (W_3) internode (4.48 mm), culm height (79.75 cm), culm dry weight cm^{-1} from N_3 internode (11.35 mg) and fresh weight of the N_1 and N_2 internodes with leaf and leaf sheath (50.15 g) were recorded from the treatment T_4 whereas control treatment T_1 gave the lowest plant height (94.00 cm), number of tillers hill^{-1} (14.58), leaf area index (2.80), leaf area hill^{-1} (389.10 cm^2), diameter of 4th (W_3) internode (3.56 mm), culm height (67.20 cm), culm dry weight cm^{-1} from N_3 internode (6.63 mg) and fresh weight of the N_1 and N_2 internodes with leaf and leaf sheath (37.64 g).

Regarding treatment combination, the highest plant height (108.50 cm), number of tillers hill^{-1} (23.73), leaf area index (4.97), leaf area hill^{-1} (457.10 cm^2), diameter of 4th (W_3) internode (4.78 mm), culm height (82.23 cm), culm dry weight cm^{-1} from N_3 internode (12.18 mg) and fresh weight of the N_1 and N_2 internodes with leaf and leaf sheath (52.02 g) were recorded from the treatment combination of V_1T_4. The lowest plant height (90.14 cm) was recorded from V_2T_1 but the lowest number of tillers hill^{-1} (13.93), leaf area index (2.68), leaf area hill^{-1} (384.90 cm^2), diameter of 4th (W_3) internode (3.43 mm), culm height (65.77 cm), culm dry weight cm^{-1} from N_3 internode (6.40 mg) and fresh weight of N_1 and N_2 internodes with leaf and leaf sheath (35.77 g) were recorded from the treatment combination of V_3T_1.

The highest chlorophyll a, chlorophyll b and total chlorophyll content in flag leaf (2.12, 1.23 and 2.93 mg g^{-1}, respectively) was found from V_1 (Badshabhog) whereas the lowest (1.72, 0.93 and 2.37 mg g^{-1}, respectively) was found from the variety V_3 (Kataribhog). Treatment T_4 showed highest (2.50, 1.70 and 3.65 mg g^{-1}, respectively) whereas the lowest (1.31, 0.47 and 1.62 mg g^{-1}, respectively) was recorded from the control treatment T_1. Treatment combination of V_1T_4 showed the highest chlorophyll a, chlorophyll b and total chlorophyll content in flag leaf (2.69, 1.80 and 3.86, respectively) whereas the lowest (1.19, 0.41 and 1.46, respectively) was recorded from V_3T_1.

Again, the variety, V_1 (Badshabhog) showed the highest 1st, 2nd, 3rd and 4th internode length (28.12, 18.18, 9.81 and 5.39 cm, respectively) whereas the lowest (26.37, 16.32, 8.10 and 5.16 cm, respectively) was from V_3 (Kataribhog). The treatment T_4 gave the highest 1st, 2nd, 3rd and 4th internode length (29.38, 19.73, 10.93 and 5.81 cm, respectively) whereas T_1 gave the lowest (25.16, 14.50, 7.48 and 4.36 cm, respectively). Treatment combination of V_1T_4 showed the highest 1st, 2nd, 3rd and 4th internodes length (30.57, 20.80, 12.80 and 6.07 cm, respectively) whereas the lowest (24.78, 13.57, 7.15 and 4.17 cm, respectively) was recorded from the treatment combination of V_3T_1.

The lowest days to 1st flowering (92.33 days), days to maturity (135.70 days), number of sterile spikelets panicle^{-1} (21.56) and spikelets sterility (14.08%) were recorded from the variety V_1 (Badshabhog) and this variety (Badshabhog) also showed the highest number of filled grains panicle^{-1} (134.90), total spikelets panicle^{-1} (156.40), grain weight hill^{-1} (7.43 g), grain yield (2.52 t ha^{-1}), straw yield (4.67 t ha^{-1}), biological yield (7.19 t ha^{-1}), harvest index (35.01%), ratio of spikelet no. to LA (4.55 cm^2) and the highest ratio of yield sink to LA (17.46 cm^2). On the other hand, the highest days to 1st flowering (94.50 days), days to maturity (138.70 days), number of sterile spikelets panicle^{-1} (23.88) and spikelets sterility (16.44%) were recorded from the variety V_3 (Kataribhog) and this variety also showed lowest number of filled grains panicle^{-1} (123.30), total spikelets panicle^{-1} (147.20), grain weight hill^{-1} (6.69 g), grain yield (2.27 t ha^{-1}), straw yield (4.37 t ha^{-1}), biological yield (6.64 t ha^{-1}), harvest index (34.14%), ratio of spikelet no. to LA (3.60 cm^2) and ratio of yield sink to LA (16.18 cm^2)

The highest days to 1st flowering (94.22 days), days to maturity (139.10 days), number of filled grains panicle^{-1} (147.80) and total spikelets panicle^{-1} (166.80) were recorded from the treatment T_4 and this treatment also showed lowest number of sterile spikelets panicle^{-1} (18.95) and spikelets sterility (11.40%).

The lowest days to 1st flowering (92.33 days), days to maturity (135.00 days), number of filled grains panicle^{-1} (109.00) and total spikelets panicle^{-1} (135.90) were recorded from the control treatment T_1 and this treatment also showed highest number of sterile spikelets panicle^{-1} (26.94) and spikelets sterility (19.83%).

Similarly, the treatment T_4 gave the highest grain weight hill^{-1} (8.13 g), grain yield (2.76 t ha^{-1}), straw yield (4.98 t ha^{-1}), biological yield (7.74 t ha^{-1}), harvest index (35.68%), ratio of spikelet no. to LA (5.55 cm^2) and ratio of yield sink to LA (18.19 cm^2) whereas control treatment T_1 gave the lowest grain weight hill^{-1} (5.76 g), grain yield (1.96 t ha^{-1}), straw yield (3.95 t ha^{-1}), biological yield (5.91 t ha^{-1}), harvest index (33.12%), ratio of spikelet no. to LA (2.58 cm^2) and ratio of yield sink to LA (14.80 cm^2).

Treatment combination of V_3T_4 showed the highest days to 1st flowering (95.33 days) and days to maturity (140.30 days) but V_3T_1 showed the highest number of sterile spikelets panicle^{-1} (27.80) and highest spikelets sterility (20.74%). Again, the treatment combination of V_1T_4 showed the highest number of filled grains panicle^{-1} (153.70), total spikelets panicle^{-1} (171.80), grain weight hill^{-1} (8.51 g), grain yield (2.89 t ha^{-1}), straw yield (5.12 t ha^{-1}), biological yield (8.02 t ha^{-1}), harvest index (36.09%), ratio of spikelet no. to LA (6.17 cm^2) and ratio of yield sink to LA (18.92 cm^2).

The lowest days to 1st flowering (91.33 days) and days to maturity (133.70 days) was recorded from V_1T_1 whereas the lowest number of sterile spikelets panicle^{-1} (18.06) and number of spikelets sterility (10.51%) were recorded from V_1T_4. Similarly, the treatment combination, V_3T_1 showed the lowest number of filled grains panicle^{-1} (106.30), total spikelets panicle^{-1} (134.10), grain weight hill^{-1} (5.47 g), grain yield (1.86 t ha^{-1}), straw yield (3.86 t ha^{-1}), biological yield (5.72 t ha^{-1}), harvest index (32.51%), ratio of spikelet no. to LA (2.45 cm^2) and ratio of yield sink to LA (14.21 cm^2).

The variety V_2 (Chiniatab) showed lowest lodging severity (Lodging score = 3.00) which indicates less than 20% of plants lodged whereas V_3 (Kataribhog) showed highest lodging severity (Lodging score = 5.00) which indicates 41-60% of plants lodged. Similarly, the lowest lodging severity (Lodging score = 0.33) was found from the treatment T_4 whereas the highest lodging severity (Lodging score = 7.67) was found from the treatment T_1. Treatment combination of V_1T_4, V_2T_2 and V_2T_4 showed no lodging whereas V_3T_1 showed maximum lodging severity (Lodging score = 9.00).

Again, the variety V_2 (Chiniatab) showed strong aroma compared to V_3 (Kataribhog) (slight aroma) and V_1 (Badshabhog) (moderate aroma). Different treatment of fertilizer management had no significant on aroma quality. The treatment combination of whereas V_3T_1, V_3T_2, V_3T_3 and V_3T_4 showed slight aroma and V_2T_1, V_2T_2, V_2T_3 and V_2T_4 showed moderate aroma.

From the above results, it may be concluded from the result that the variety V_1 (Badshabhog) showed best performance regarding growth and yield compared to V_2 (Chiniatab) and V_3 (Kataribhog). Again, the treatment T_4 showed best results on growth and yield of rice. In terms of lodging resistance and aroma quality, V_2 (Chiniatab) gave best performance followed by V_1 (Badshabhog). In case of treatment combinations, V_1T_4 performed best in producing higher yield of rice than other treatment combinations. Similarly, V_1T_4, V_2T_2 and V_2T_4 performed best lodging resistance whereas V_2T_1, V_2T_2, V_2T_3 and V_2T_4 showed strong aroma.

Recommendation

The present research work was carried out at the Sher-e-Bangla Agricultural University and one season only. Further trial of this work may be conducted in different AEZ of Bangladesh and it is needed before the final recommendation.

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APPENDICES

Appendix I. Agro-Ecological Zone of Bangladesh showing the experimental location

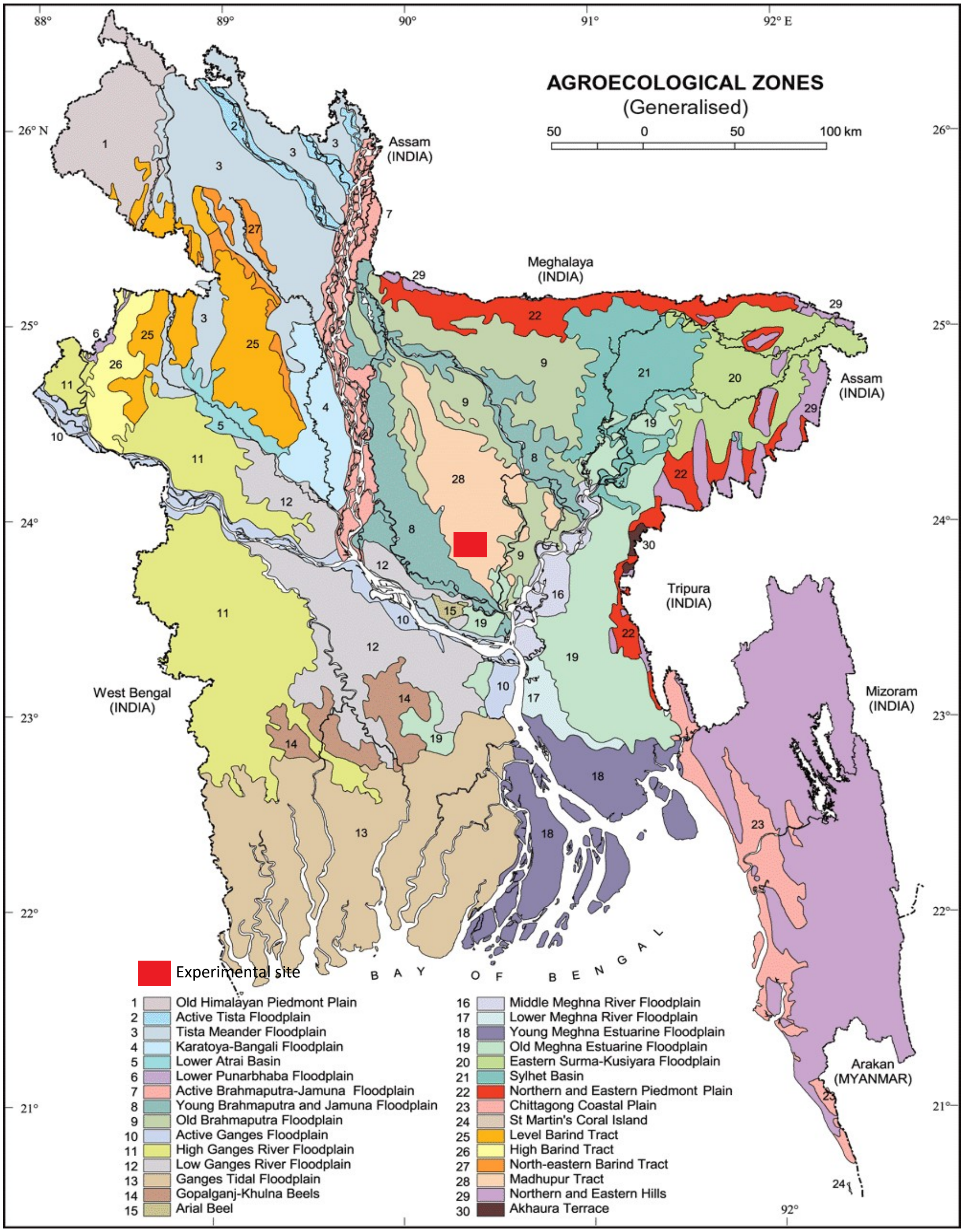


Figure 10. Experimental site

Appendix II. Monthly records of air temperature, relative humidity and rainfall during the period from November, 2019 to May, 2020.

Year	Month	Air temperature (°C)			Relative humidity (%)	Rainfall (mm)
		Max	*Min*	*Mean*		
2019	November	28.60	8.52	18.56	56.75	14.40
2019	December	25.50	6.70	16.10	54.80	0.0
2020	January	23.80	11.70	17.75	46.20	0.0
2020	February	22.75	14.26	18.51	37.90	0.0
2020	March	35.20	21.00	28.10	52.44	20.4
2020	April	34.70	24.60	29.65	65.40	165.0
2020	May	32.64	23.85	28.25	68.30	182.2

Source: Bangladesh Meteorological Department (Climate division), Agargaon, Dhaka-1212.

Appendix III. Characteristics of experimental soil analyzed at Soil Resources Development Institute (SRDI), Farmgate, Dhaka.

A. Morphological characteristics of the experimental field

Morphological features	**Characteristics**
Location	Agronomy Farm, SAU, Dhaka
AEZ	Modhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained
Cropping pattern	Not Applicable

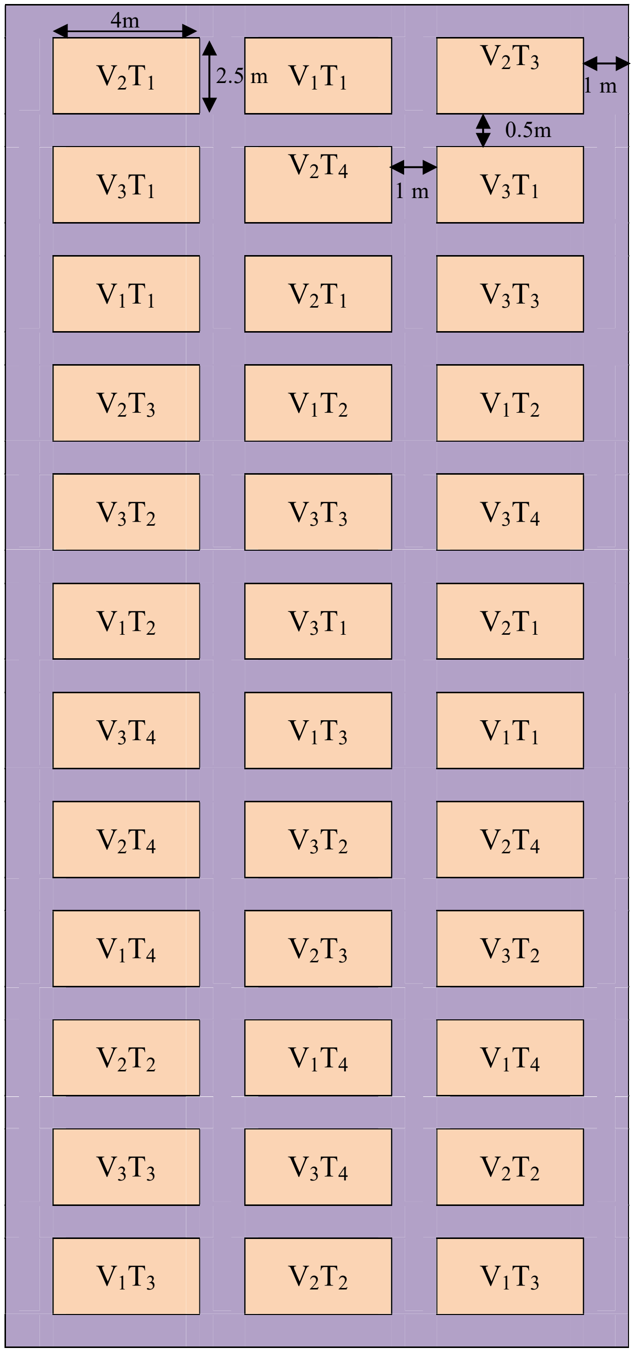
Source: Soil Resource Development Institute (SRDI)

B. Physical and chemical properties of the initial soil

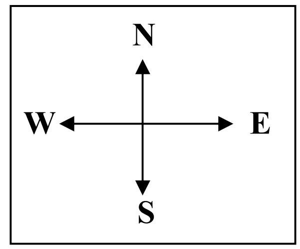
Characteristics	**Value**
Partical size analysis % Sand	27
%Silt	43
% Clay	30
Textural class	Silty Clay Loam (ISSS)
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20
Exchangeable K (me/100 g soil)	0.1
Available S (ppm)	45

Source: Soil Resource Development Institute (SRDI)

Appendix IV. Layout of the experiment field



Legend



Treatments

Factor A: Variety

1. V_1 = Badshabhog
2. V_2 = Chiniatab (awnless)
3. V_3 = Kataribhog (awnless)

Factor B: Fertilizer management

1. T_1 = {30(BS) +20 (MT) + 10 (BPI)} kg ha^{-1} + no silicon and cow-dung
2. T_2 = {30(BS) +20 (MT) + 10 (BPI)} kg ha^{-1} + silicon (450 SiO_2 kg ha^{-1}) + no cow-dung
3. T_3 = {30(BS) +20 (MT) + 10 (BPI)} kg ha^{-1} + No silicon + cow-dung (6 t ha^{-1})
4. T_4 = {30(BS) +20 (MT) + 10 (BPI)} kg ha^{-1} + silicon (450 SiO_2 kg ha^{-1}) + cow-dung (6 t ha^{-1})

**BS= basal dose; MT= mid-tillering and BPI= before panicle initiation*

Figure 11. Layout of the experimental field

Appendix V. Mean square of plant height, number of tillers hill^{-1}, leaf area index, leaf area hill^{-1} and diameter of 4th internode of aromatic rice varieties as influenced by different fertilizer management

Sources of variation	Degrees of freedom	Mean square				
		Plant height (cm)	Number of tillers hill^{-1}	Leaf area index	Leaf area hill^{-1} (cm^2)	Diameter of 4th (W_3) internode (mm)
Replication	2	0.343	0.039	0.037	9.599	0.235
Factor A	2	267.58*	20.86*	1.155**	966.919*	NS
Factor B	3	179.91*	87.57*	5.793*	5871.26*	1.656**
AB	6	1.930**	2.472*	0.140**	54.166*	0.209**
Error	22	0.954	0.602	0.018	13.908	0.016

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix VI. Mean square of culm height, culm dry weight cm^{-1} from N_3 internodes and fresh weight of the N_1 and N_2 internodes with leaf and leaf sheath as influenced by different aromatic rice varieties and fertilizer management

Sources of variation	Degrees of freedom	Mean square		
		Culm height (cm)	Culm dry weight cm^{-1} from N_3 internode (mg)	Fresh weight of the N_1 and N_2 internodes with leaf and leaf sheath
Replication	2	0.600	0.001	0.351
Factor A	2	52.181*	8.891*	58.069*
Factor B	3	288.74*	39.54*	288.99*
AB	6	1.529*	0.787**	1.626*
Error	22	2.035	0.026	1.386

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix VII. Mean square of chlorophyll content in flag leaf of aromatic rice varieties as influenced by different fertilizer management

Sources of variation	Degrees of freedom	Mean square of chlorophyll content in flag leaf		
		Chlorophyll a	Chlorophyll b	Total chlorophyll
Replication	2	0.005	0.035	4.797
Factor A	2	NS	NS	0.965**
Factor B	3	2.807*	2.748*	7.868*
AB	6	0.030**	0.023**	0.075**
Error	22	0.014	0.030	0.041

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix VIII. Mean square of internodes length of aromatic rice varieties as influenced by different fertilizer management

Sources of variation	Degrees of freedom	Mean square of internodes length			
		1st	2nd	3rd	4th
Replication	2	0.066	0.060	0.140	0.253
Factor A	2	9.804*	11.82*	9.028*	NS
Factor B	3	34.55*	51.59*	22.03*	3.607*
AB	6	0.973**	0.447**	2.123*	0.327**
Error	22	0.332	0.257	0.104	0.036

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix IX. Mean square of yield contributing parameters of aromatic rice varieties as influenced by different fertilizer management

Sources of variation	Degrees of freedom	Mean square of yield contributing parameters					
		Days to 1st flowering	Days to maturity	No. of filled grains panicle^{-1}	Sterile spikelets panicle^{-1}	Total spikelets panicle^{-1}	Spikelets sterility (%)
Replication	2	0.361	0.583	1.727	0.259	2.882	0.081
Factor A	2	15.44*	28.00*	408.923*	16.428*	261.426*	17.004*
Factor B	3	5.852*	30.74*	2969.19*	128.29*	1863.62*	140.65*
AB	6	0.185**	0.519**	23.907*	0.602**	18.518*	0.456**
Error	22	0.361	0.523	12.221	2.146	11.962	0.801

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix X. Mean square of yield parameters of aromatic rice varieties as influenced by different fertilizer management

Sources of variation	Degrees of freedom	Mean square of yield parameters						
		Grain weight hill^{-1}	Grain yield	Straw yield	Biological yield	Harvest Index (%)	Ratio of spikelet no. to LA (cm^{-2})	Ratio of yield sink to LA (mg cm^{-2})
Replication	2	0.007	0.001	0.003	0.001	0.247	0.002	0.012
Factor A	2	1.678**	0.193*	0.268*	0.917*	NS	2.729*	NS
Factor B	3	9.963*	1.152*	1.941*	6.081*	11.11*	18.74*	20.51*
AB	6	0.027**	0.003**	0.006**	0.014**	0.150**	0.295*	0.034**
Error	22	0.073	0.011	0.012	0.014	0.071	0.039	0.083

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix XI. Mean square of lodging severity and aroma test as influenced by different aromatic rice varieties and fertilizer management

Sources of variation	Degrees of freedom	Mean square of lodging severity at maturity	Mean square of aroma test
Replication	2	0.002	0.001
Factor A	2	0.214**	0.136**
Factor B	3	1.071**	NS
AB	6	0.011**	0.007**
Error	22	0.001	0.001

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level